THE HAWAIIAN PLANTERS' RECORD

Vol. XLVIII THIRD QUARTER 1944 No. 3

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

Why a Diversified Crops Committee, H.S.P.A.?

By Harold L. Lyon

The following statement was prepared during the summer of 1943 in answer to he questions: "Why did the H.S.P.A. appoint a Committee to promote the cultivation of crops other than sugar cane and pineapples on Hawaii's arable lands: what has this Committee done and what does it propose to do?"

The first world war caught the residents of Hawaii quite unprepared to produce all of their own food: in fact, the possibility that it might become necessary for them to do so had never occurred to most of the people in these Islands; so when, early in 1917, it became suddenly apparent that this Territory might be denied a considerable part, or all, of the food which it was accustomed to receive from the outside world, a realization of the situation struck the community like a bombshell; it was evident that something drastic had to be done, and done at once, to forestall a calamity. There was no plan in existence to meet such an emergency and no government agency prepared to make a plan and put it into effect. Recognizing the critical situation and the need for prompt and decisive action, the H.S.P.A. stepped into the breach, took on the job of food production and assigned it to its Experiment Station. The Station accepted the mandate, analyzed the problem, and started operations along the lines which appeared to be most certain to lead to success. The Trustees made available to the Experiment Station ample funds to implement its food-production program and progress was rapid and results satisfactory. While many people in Hawaii were deprived of some of the foods to which they were accustomed, still no one in Hawaii suffered during the first world war for lack of good food. The extreme crisis which threatened never developed. However, had it arrived, we should have been able to feed ourselves.

The methods adopted by the Experiment Station in attacking the problem of food production are well illustrated in the Food Number of *The Hawaiian Planters' Record*, a publication of some 115 pages, issued in June 1917. The first four pages taken from a copy of that number of the *Record* are reproduced here.

THE
HAWAIIAN
PLANTERS' RECORD

VOL. XVI JUNE, 1917 NO. 6

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association

Hawaii May Have to Feed Herself.

The Federal Government has asked this Territory to produce its own food supply in so far as possible and circumstances may actually compel us to live entirely on what we produce if the war continues for two years or more.

The world's surplus of foods is already exhausted and the feeding of the entire human race is now actually reduced to a hand-to-mouth proposition.

Under such circumstances we can readily see that the stream of foodstuffs coming to these Islands from the mainland may be seriously curtailed within the present year.

We Must Not Reduce Our Sugar Crop.

As a food sugar heads the list as a producer of life-sustaining energy. A pound of sugar has more food value than a pound of flour, rice, beef or beans. Sugar is Hawaii's contribution to the world's food supply. It is just as much Hawaii's duty to produce a maximum sugar crop as it is Iowa's duty to produce a maximum output of corn and hogs.

This being the case, we must not encroach upon our sugar lands to the detriment of our sugar yields. We have got to produce our local food supply by more intensive agriculture, by the cultivation of all fallow fields and by the fullest utilization of all suitable lands which are now idle or only doing a very small fraction of their possible duty.

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We Must Have Meat, Milk and Eggs.

Mainland hay and grain feeds are now soaring to unbelievable prices and may soon be, to us, unobtainable at any price. An impending milk shortage is already discernable and a rapid decrease in hog and poultry products may be expected.

So far as cattle and horses are concerned the feed shortage can be relieved to a large extent by using the excess of green cane tops and molasses now going to waste on the plantations. In addition to feeding the cane tops when fresh, they may be made into silage or shredded and cured into hay for use during the off season.

With the feed afforded by the present ranches and the cane tops and molasses available for stock feed on the plantations Hawaii can feed enough cattle to supply the milk and beef requirements of all the people on these Islands and eventually have beef for export.

The conversion of cane tops and molasses into milk and beef calls for no additional land and no more additional equipment or labor than would be well paid for by the values produced when feeds are at normal prices.

Hogs will eat some silage and a considerable amount of pineapple refuse, but we must grow corn, sweet potatoes, beans and peanuts to take the place of the starchy and nitrogenous grain and mill products now imported for hog feed.

Home grown corn, sweet potatoes, milo maize, sunflower seed and pigeon peas will fill the grain requirements of our poultry.

Belgian hares thrive on the green pods and leaves of the lowland koa. They are very fond of pualele and will eat honohono and many other of the common weeds. The prunings from an hibiscus hedge are a welcome addition to their diet. The feeding of Belgian hares, therefore, requires no extra agricultural effort. It is purely a matter of conservation.

What Crops Shall We Plant?

We do not recommend the trial of new food plants at this time. We cannot afford to sacrifice a sure crop in order to try a new and uncertain one. We already know that certain things can be grown successfully on our lands and seeds and cuttings are already available for their planting. Standard and tested crops such as rice, taro, sweet potatoes, bananas, beans and peanuts should receive first attention. Corn should be grown when and where conditions suit it.

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The food materials imported by these islands during 1916 represented the actual amount of additional food which we should have had to produce during that year to be self-supporting. For practical purposes these imports, listed on pages 446-449, may be taken as representing the amount by which we must increase our yearly output if we are to become self-supporting. We cannot hope to duplicate these commodities kind for kind, but we can easily reckon their food value in terms of protein, fats and carbohydrates, and then direct our energies towards producing the required amounts of these three nutrients. The tables on pages 462-465 supply the additional data necessary to make these computations.

For Carbohydrates: While we will probably use an increased amount of sugar, still the greater part of the carbohydrates now imported must be replaced by starchy foods such as rice, taro, corn, bananas and sweet potatoes.

When all the idle lands suitable for rice and taro are under cultivation, their output will make only a small contribution towards our total requirements. Corn does well in certain districts only and can not be recommended for general planting. While the banana supplies an excellent food, it would not, for several reasons, be selected as an emergency starch producer

The sweet potato, then, is left as our last hope and we could not ask for a brighter one. The sweet potato is a rapid growing, quick maturing crop and will yield more digestable carbohydrates per acre per year than any other food crop suited to our conditions.

We can increase our sweet potato yield a hundred fold without diminishing our sugar or pineapple crops.

For Protein and Fat: To produce the protein and fat now imported, which we cannot replace by an increased production of meat, milk, butter and eggs, we must grow beans and peas of various sorts. All of the well-known garden varieties of beans and peas are rich in protein and at the same time contain some fat and considerable carbohydrates. Soy beans and peanuts are especially rich in fat; the former is not a sure crop in Hawaii, however, but the latter can be relied upon to give good returns. Peanuts are easily grown and the seeds contain forty to fifty per cent of fat.

The coconut is a very important source of fat in most tropical countries and it is unfortunate that these Islands have not now a well-developed coconut industry. Coconuts should be planted now to help out in future emergencies.

Green Vegetables: Hawaii grows a reasonable amount of this

class of produce under normal conditions and an over-production of garden truck will be the most natural result of the present grow-your-own-food agitation.

We feel that this phase of the food production campaign needs no special promotion on our part. Overproduction of perishable garden truck will result in waste of produce and discouragement of its growers.

Beans and sweet potatoes can be fed to horses, cattle and hogs in lieu of grain. They can be stored for months or shipped to distant markets.

There is no doubt but that Hawaii can feed herself If compelled to do so, beans and sweet potatoes must be her "staff of life."

MISCELLANEOUS FOOD CROPS ON SUGAR PLANTATIONS.

By L. D. Larsen

The concensus of opinion among those who have studied the situation indicates that sugar is by far the most important commodity that can be raised on our plantations at the present time. In view of the national food shortage we are urged to use every effort possible for increasing or at least upholding our usual sugar production. No one suggests curtailing the sugar area to produce other food stuffs.

It is imperative, however, that other food crops be grown on a much larger scale in these Islands than has heretofore been the case, and it is evident that a large share of this increased production has to take place on the sugar plantations.

The object of this article is to point out some of the means that have been suggested or which have already been adopted in various parts of the Islands for accomplishing this end.

For the sake of brevity we shall discuss our subject under four separate headings:

1. Waste lands,
2. Fallow lands,
3. Camp gardens,
4. Interplanting with cane.

On pages following those reproduced were articles describing the more important food crops that could be grown successfully in Hawaii and giving pertinent information regarding their culture. One article gave the name and quantity of each and every kind of food that had been brought into the Territory during the preceding year. This enabled us to estimate the nature and amounts of additional food materials which would have to be produced locally should Hawaii be compelled to feed herself.

Farmers' Bulletin No. 142 of the U. S. Department of Agriculture (1917), entitled "Principles of Nutrition and a Nutritive Value of Food," was reprinted in full in this issue of the *Record* and enabled anyone to compute the relative values of various food materials. On the whole, this Food Number of the *Planters' Record* constituted a practical manual supplying all the data necessary for formulating and executing a program of food production for the Territory.

The fact that a realization of the necessity for a food-production program came one day in 1917 and the financing and launching of the program were virtually completed the next day is a striking example of the rapid-fire efficiency of the H.S.P.A. organization. Any situation arising that jeopardizes the economy of this Territory which can be appropriately handled by the H.S.P.A. may be considered, and its alleviation provided for, within a few hours after its recognition.

Recalling the difficulties in food production which suddenly confronted Hawaii during the first world war, the H.S.P.A. was determined that the Territory should not be caught equally unprepared should a later war involve these Islands. It was realized that should an emergency arise, say in 1940, that required these Islands to produce all of their own food, the problem would be far more difficult than was the problem in 1917 so, in 1935, the H.S.P.A. organized its Diversified Crops Committee, one of the prescribed functions of which was to draw up plans for food production to meet any emergency that might check or stop the flow of food supplies into Hawaii.

As an easy means of describing the efforts of this Committee in planning for food-crop production to meet any emergency, we reproduce a letter written to Governor Poindexter in June 1941:

June 19, 1941.

The Honorable Joseph B. Poindexter,
Governor of Hawaii,
Iolani Palace, Honolulu, Hawaii.

My dear Governor Poindexter:

In compliance with your request, I submit the following brief statement regarding what has been done and what should be done to insure an adequate food supply for Hawaii in case of an emergency.

The Diversified Crops Committee:

In 1935 the H.S.P.A. called together, as a Diversified Crops Committee, a group of men representing all phases of agricultural endeavor in the Territory. Ever since its inauguration, this Committee has functioned continuously and at the present time its membership is as follows:

H. P. Agee	A. L. Dean	H. L. Lyon
J. H. Beaumont	A. D. Ednie	W. W. G. Moir
F. W. Broadbent	Col. Casey Hayes	H. H. Warner
D. L. Crawford	L. D. Larsen	Neil Webster

While the primary function of the Diversified Crops Committee was to find new crops that could be grown in the Territory with profit to the growers, it has from the very first given

much attention to plans for producing, locally, crops in such quantities and of such a nature as would provide the entire population with adequate subsistence in case some emergency stopped the flow into the Territory of foodstuffs from outside sources. During the past year, all the efforts of this Committee have been focussed on this one objective.

A Food Administration with Authority an Obvious Necessity:

The Diversified Crops Committee has at all times held the opinion that whenever an emergency develops necessitating the local production of a large part or all of the food required to feed the people in this Territory, a Food Administration would be set up and financed by the Federal Government, and given unlimited powers to requisition land, water, labor, machinery, fuel and all seeds and cuttings of food plants.

The Diversified Crops Committee has, through long-continued efforts on the part of its members and their associates, worked up feasible plans for food and feed production in this Territory with the intention of placing these plans at the disposal of a Food Administration if, and when, such an Administration was created.

On request, the Diversified Crops Committee can supply inventories of stocks of essential foods, feeds, fuels, etc. present at the time in the Territory and can also provide an estimate of the cost of any operation which it recommends.

If Prepared for the Worst, Any Lesser Emergency Can Be Easily Handled:

It is quite probable that if an emergency develops, the Territory will experience a gradual curtailment of transportation facilities but we should be prepared to meet promptly the worst possible situation. As the bulk of the Territory's population resides on the Island of Oahu, the most serious situation that can arise is the complete isolation of Oahu, not only from the mainland but from the other islands in the group as well. The Diversified Crops Committee has prepared a food production plan to meet this critical situation should it ever arise. If some agency is authorized and financed to carry out this plan to meet the worst possible situation, it will be able to cope rather easily with any situation of lesser severity which may be inflicted upon us. The Diversified Crops Committee has, therefore, drawn up a Basic Plan to meet the extreme situation; this plan being so drawn that it can be put into effect by increments, the entire plan becoming effective only when the extreme situation is about to be realized.

Adequate Funds Should Be Made Immediately Available:

If the extreme situation develops—that is, complete isolation of Oahu—the conditions which make this possible will render such exposed sections of the Island as Waianae, Kahuku and Waimanalo unfit and unreliable for farming operations; therefore, plantings for the extreme emergency should be confined to the four major and centrally located plantations. The lands of these plantations are among the most highly productive in the Territory and their use for growing diversified crops will represent a heavy financial investment. The minimum area of irrigated lands required for planting under the Basic Plan is 8,700 acres. These sugar cane lands, when requisitioned, will all be carrying heavy crops of cane and it will require much energy, labor and expense to get this cane out of the ground, put the land in shape and plant other crops. Seeds and propagating material for the crops to be planted must be grown or purchased.

Seeds for some crops can be purchased from outside sources but those for others, such as pigeon pea, must be grown locally. The sweet potato should be our most extensively planted food crop as it is our most reliable, but we shall have to have much more propagating material than is now available in the Territory. Steps should be taken at once to secure appropriate land and grow thereon the propagating material of the essential crops which will be required for the initial plantings under the Basic Plan.

The planting, cultivating and harvesting of the food crops that must be grown will require special machinery not now to be found on sugar plantations or elsewhere in the Territory. The procuring of this machinery should be attended to at once as it will take time to get it here from the mainland. Following recommendations of the Diversified Crops Committee, the H.S.P.A. has already invested several thousand dollars in emergency machinery, but this will only serve to demonstrate what is needed. The H.S.P.A. has also spent many thousands of dollars on the promotion of diversified crops through field and feeding experiments carried on under the supervision of the Diversified Crops Committee.

We Must Grow Crops for Feed:

In addition to growing food crops for human consumption, we must grow crops to feed beef cattle, dairy cattle, hogs and poultry, for we must have meat, milk and eggs. The by-products of the sugar and pineapple industries will be employed to advantage as feed, but these will not go very far towards fulfilling requirements. We must grow forage crops for cattle, root crops for hogs and seed crops for poultry.

Protein Foods and Feeds:

A life-sustaining diet for all animals including man must provide a considerable amount of protein, that is, organic compounds containing nitrogen. Hawaii's standard crops are notoriously rich in carbohydrates but very low in protein. As a consequence, the Territory imports, under normal conditions, large amounts of foods and feeds which supply protein. To provide adequate protein for human consumption and for stock feed will be one of the most serious problems to be solved in an extreme emergency.

All plants can make protein out of carbohydrates and inorganic nitrogen, but animals do not possess this ability, so must derive all their proteins from plants. The sugar cane, pineapple and banana make protein for their own bodies, but place very little of it in the products which we recover, so, in an emergency, we must grow plants that put protein in that portion of their bodies which we, as humans, use for food. Bean plants deposit a lot of protein in their seeds and, as we can grow many varieties of beans successfully in Hawaii, they constitute one crop on which we can rely for a considerable part of our protein in an emergency.

Another crop rich in protein, the cultivation of which is being advocated by the Diversified Crops Committee, is yeast. This lowly organism can be grown easily in a weak sugar solution to which has been added ordinary fertilizer salts. It feeds on the sugar and, picking up the nitrogen and mineral elements, builds up protein, growing at a prodigious rate. The yeast organism does not construct a complicated body but merely clothes its living substance with a thin membrane. A mass of dry yeast, therefore, is largely protein. Under favorable conditions, which are easily maintained in any climate, a crop of yeast grows to maturity in less than 24 hours, so it is quite possible to harvest a crop every day in the year.

At a pilot plant in Honolulu, financed by the H.S.P.A., all the details of yeast production as a commercial crop have been worked out. The dry product is 50 per cent protein and very rich in the vitamins of the "B" complex. It is quite palatable and a number of people have, for some time, been eating it regularly to determine its value as a source of protein in the human diet. Their reactions are all very favorable. Up to the present time, most of the output of this pilot plant has been used in feeding experiments at the University with cattle, hogs and poultry. The results of these experiments clearly indicate that yeast is an excellent source of protein for these food-yielding animals. However, since this yeast has proved to be a good protein food for humans, it would be poor economy to feed it to beef cattle in an emergency, for it will be necessary to feed at least 10 pounds of yeast protein for every pound of protein recovered in beef.

Since an abundance of sugar will always be available on Oahu, the Diversified Crops Committee recommends that adequate facilities be provided so that in an emergency yeast may be produced in large quantities for food and feed. Under our conditions, the culture of yeast affords the surest and quickest method of producing the essential protein.

Stores and Storage Most Essential:

It will be at least six months after operations under the Basic Plan have been started before its returns will fully meet the needs of the population, so it is essential that we have on hand supplies of food and feed to carry us through this critical period.

We have learned by experience that crops cannot be successfully grown on our lands unless they are supplied with adequate fertilizers and as all fertilizers used in Hawaii are brought in from outside sources, it is essential that an adequate supply of these materials be imported and held in reserve for use in case an emergency develops.

In order to combat the diseases and insect pests which are certain to attack the divers crops which we must grow in an emergency, we should have on hand an adequate supply of appropriate insecticides and fungicides. These materials should be brought into the Territory while transportation facilities are still available.

Most of the energy consumed in the Territory outside of sugar factories is derived from fuel oil, Diesel oil and gasoline brought from the mainland. We cannot have electric lights and electric power if the flow of these fuels from the mainland is stopped. Most of the water used for domestic purposes and irrigation on Oahu is pumped from wells with power derived from fuel oil. Deprive Oahu of fuel oil, and the water supply of Honolulu would fail completely, while most of the cane fields on the Island would have to go without water and the crops which they carry would be ruined. Deprive Oahu of Diesel oil and gasoline and it would be impossible to operate the machinery necessary to the cultivation of field crops. It is most essential, therefore, that if an extreme emergency is impending, large supplies of fuel oil, Diesel oil and gasoline be held in storage on Oahu for, if our power supply fails, we will be unable to survive long.

Cultivation of Truck Crops in Hawaii Not Profitable Under Normal Conditions:

The chief aim of agriculture is to capture radiant energy by means of crops which store it in products which can be utilized by man. Of all known crops, sugar cane is the most efficient producer of such products and, consequently, its cultivation adds more to our national resources in a given time than can the cultivation of any other crop. So long as normal transportation between Hawaii and the mainland can be maintained, Hawaii can contribute most to our national resources by growing sugar for shipment to the mainland, and most to our national prosperity by buying from the mainland products produced more efficiently there than they can be produced in Hawaii.

Hawaii is tropical and its fields are not suitable to the cultivation of temperate zone crops. If such crops are grown, the yields are not comparable with those obtained in temperate climes.

It should be obvious to any student making a careful examination of the situation that anyone undertaking the production of truck crops in Hawaii on a scale sufficient to satisfy the local demand for these crops is embarking on a course that will lead to financial disaster if mainland produce has continued access to our market. If Hawaii must undertake the production of food crops to tide her through a national emergency, the Federal Government should underwrite the enterprise, as it cannot survive when the emergency is passed and will be liquidated at a considerable loss to its promoters.

Yours respectfully,

(Signed) Harold L. Lyon,
Director.

After carefully considering the confusion and even panic which might possibly be induced by such a course, the Diversified Crops Committee early in 1941 instigated and promoted among the civilian population throughout the Territory a campaign of buying and storing for a possible emergency such food products as rice, flour, beans and canned goods. The people of Hawaii promptly grasped the idea and, with enthusiasm but without any hysteria, bought and stored on their own premises large amounts of food. This relieved much warehouse space which was promptly filled with new goods from the mainland. By buying and storing food materials in the early months of 1941, the people of Hawaii contributed much to the favorable food situation which has been constantly maintained in Hawaii up to the present time.

The Diversified Crops Committee carried on investigations, financed and conducted experiments in the field and, on the basis of its findings, made plans for food production to meet any emergency that might arise. There were certain very important lines of investigation which it could not undertake and, because of this, it could not obtain certain information which was most essential in rounding out its plans. The misgivings of the Committee were expressed in a letter to the Trustees which we reproduce hereunder:

August 11, 1941.

The President and Trustees of the
Hawaiian Sugar Planters' Association,
Honolulu, Hawaii.

Dear Sirs:

The Diversified Crops Committee, H.S.P.A., has directed its attention in recent months almost exclusively to the formulation of plans under which the Territory of Hawaii might produce sufficient food to sustain its population in case an emergency stops the flow of foods from the mainland.

You have been advised from time to time of the Committee's progress with these plans, which are now nearing completion. Under instructions from the Committee, its Chairman discussed the food production situation with Governor Poindexter and, at his request, prepared a statement, a copy of which is attached hereto.

At the last meeting of the Diversified Crops Committee (August 1), it was moved, seconded and voted:

> "THAT the chairman of the committee present to the Trustees the serious nature of the whole problem of production and storage as brought out in the discussion by the members present and request the instructions of the Trustees as to the future course of the committee."

If the flow of foods to Hawaii from the mainland is stopped, the flow of other materials will also be stopped. It will be absolutely essential, therefore, that we have on hand in this Territory, when transportation is halted, all the materials necessary to implement our food production plans: otherwise, our plans will be of no avail. When the crisis arrives, we should have immediately available ample planting material of the crops to be grown and the special machinery required to handle these crops. We should have in storage supplies adequate for a year or more of the fertilizers, insecticides and fungicides required in the culture of our special food crops. We should also have in storage large quantities of feeds for our dairy cattle and poultry and finally, we should have in reserve large supplies of fuel, for our food-production operations cannot be carried on, as planned, after our fuel supply is exhausted. The Diversified Crops Committee has repeatedly pointed out the absolute necessity of obtaining these essentials prior to the emergency, but no steps are being taken to provide them. Lacking these essentials, the Committee's plans cannot be executed so it will have but wasted time in making them.

The length of time that Oahu can survive a total blockade will be determined by the amount of fuel on hand to operate its essential utilities. Honolulu's water supply, electric current, gas and transportation facilities all depend upon imported fuel. The cultivation of food crops on a major scale and their distribution will consume much fuel. It should be obvious that fuel will be the very backbone of Oahu's resistance to a blockade; yet, the fuel question is receiving scant attention. The importation and storage of fuel and plans for its conservation during any emergency should be receiving the immediate attention of the very best men available for the job. The conservation of fuel will be one of the most important measures in defense and every operation proposed as an emergency measure should be carefully examined with reference to its probable fuel requirements before it is approved.

When an emergency is impending, it will be necessary to obtain and store in the Territory enough food to feed its population until locally produced foods are available in sufficient amounts. It is estimated that it will cost around 2½ million dollars to provide sufficient imported food to carry the population on Oahu through the first six months of an emergency. It will cost equally as much to finance our food production plans for Oahu and carry them through the second six months of an emergency. The question naturally arises, therefore, would it not be safer and more economical to buy and store a year's food supply rather than attempt to fully implement our food production plans. It certainly would be safer, for the cultivation of temperate-zone food crops on these tropical islands is always a hazardous undertaking, for crop failures are the rule rather than the exception. The concentrated foods required for the second six months of an emergency would hardly be more bulky for transportation than the fertilizers,

insecticides, fungicides, special machinery, feeds and extra fuel which it will be necessary to import in order to execute our food-production plans. The use of imported foods would be a good way to conserve fuel.

Now, we do not wish to have you gain the impression that your Diversified Crops Committee holds that its food production plans cannot be carried through, but it does wish to let you know that the steps to implement these plans, which must be taken before transportation is curtailed, are not being taken and that when transportation is curtailed, it will be too late to take these steps. We wish to make this clear at this time so that we will not be called upon to do the impossible when an emergency arrives.

Yours very truly,

DIVERSIFIED CROPS COMMITTEE, H.S.P.A.,
By (Signed) HAROLD L. LYON, Chairman.

In November 1941, the Diversified Crops Committee transmitted to the Trustees of the H.S.P.A. detailed plans for food production throughout the Territory; plans which might be implemented to a sufficient degree to meet any food emergency that could arise, ranging from one entailing a slight decrease in imported foods up to one imposed by a total blockade, when we should have to produce enough food to supply all the needs of the Territory. These plans were made available by the H.S.P.A. to the Army and to any and all other government agencies that might wish to have them. Immediately following the attack on Pearl Harbor, martial law was imposed upon Hawaii and the United States Army immediately assumed control over Hawaii's food supply and responsibility for maintaining it.

There is a very great diversity in the kinds of foods that might be supplied to feed adequately the people in this Territory. The *most pleasant situation* prevails when everybody gets all they want of each kind of food that they are accustomed to. The *most unpleasant situation* would exist when everybody was supplied each day with a subsistence ration only, and this composed of the same commonplace ingredients day after day. Now, no one relishes the experience of living for months almost entirely on sweet potatoes and beans: yet, that is exactly what they would have to do should Hawaii be deprived of its ocean transportation facilities. Despite stupendous difficulties which it could not mention but had to overcome, Hawaii's Food Administration has, since December 7, 1941, kept the people of this Territory unbelievably close to that "most pleasant situation" outlined above. In no other locality in the United States have the inhabitants been so well supplied with the necessities and luxuries of modern life as have the civilians in Hawaii. This is the more remarkable because most of these necessities and luxuries had to be brought to the Territory on steamers crossing submarine-infested waters and during a period when rapid transportation of military personnel, equipment and supplies was most urgent. Taking everything into consideration, the people of Hawaii should have only admiration and praise for the men who have managed to keep an abundance of good food always available to the people of this Territory.

Immediately following the outbreak of war, the Food Administration in the Office of the Military Governor took over all of the functions which the Diversified Crops Committee had previously performed voluntarily. This was exactly what the Diversified Crops Committee advocated and anticipated, as expressed in our letter of June 19 to Governor Poindexter. Although relieved of the leadership and of all responsibilities in the field of food production, the Diversified Crops Committee has continued in existence, but has had no part in the execution of the emergency

food-production program. Under the circumstances, the individual members of the Committee and their subordinates have made their contributions towards food production through the Food Administration rather than through the Diversified Crops Committee, H.S.P.A.

As soon as peace is reestablished throughout the world and we can again secure materials from all corners of the earth, the Diversified Crops Committee, H.S.P.A., will resume its search for new crops that can be grown in Hawaii with profit to the growers.

Experimental Forest Planting

Mauna Kea, Island of Hawaii

By L. W. Bryan

In 1909–1910 Forester Hosmer imported from the mainland and Australia a number of different species of conifers and hardwoods for experimental planting. The object of this experiment was "to introduce into the forest flora of the Territory of Hawaii valuable timber trees from the temperate zone with the idea of ultimately turning to economic account, through timber production, the upper slopes of the higher mountains of the Territory."* The species introduced were planted out at different elevations on the slopes of Haleakala on Maui, and Mauna Kea on Hawaii. Originally the planted areas were protected by stock-proof fences but when the writer first visited the plots on Mauna Kea in 1921, all of the fences were found to be in very poor condition, the trees were unprotected, and wild sheep had done considerable damage.

Pinus jeffreyi and *Pinus coulteri*, Plot No. 1, elevation 7,450 feet, Mauna Kea at Puu Laau.

On Hawaii four plots were located all on the west slope of Mauna Kea and briefly described as follows:

Plot No. 1—Puu Laau.....elevation	7,450 feet
Plot No. 2—Puu Ulaula .....elevation	9,000 feet
Plot No. 3 .....elevation	10,875 feet
Plot No. 4—Puu Kemole .....elevation	7,130 feet

* Kraebel, C. J., 1922. Report on experimental forest planting at high altitudes of Maui and Hawaii. The Hawaiian Forester and Agriculturist, 19: 151–158.

As Plots Nos. 3 and 4 contain comparatively few trees (Plot No. 3 only 1 and Plot No. 4 only 13), and as they have remained unprotected from damage by wild sheep, they will not be included in this summary. Fences around Plots Nos. 1 and 2 were rebuilt in 1926 and these fences have been maintained since in stock-proof condition.

Measurements were made in 1921 by Kraebel* and Bryan; in 1927 by Bryan and Lindsey; in 1933 by Bryan and Kawai; and in 1944 by Yamayoshi and Kawai. Spot measurements were made in 1921 and averages arrived at for each species. In 1927 each individual tree was carefully measured and a copper tag bearing a reference number was placed thereon. This same method was followed again in 1933 and in 1944, and an accurate record is available for each tree growing in these two plots.

The original list of trees planted by Hosmer contains the names of many species which apparently did not survive as no specimens were found alive in 1921. The original list of species tested contained the names of 49 conifers and 37 hardwoods. Failure of many of the species planted, particularly the hardwoods, can be attributed to the fact that they were planted at too high an elevation and on the dry slope of the mountain. Since then most of the same species of hardwoods have been planted at lower elevations (5000 to 6000) on the wet side of the mountain and have proved successful. Of the original hardwoods planted only one species, *Eucalyptus robusta,* has survived. Seven trees of this species are still growing in Plot No. 4 at Puu Kemole.

Species that have survived are shown in the following tabulation with average of measurements taken at the four periods mentioned.

Species	Plot	1921	1927		1933		1944	
		Avg. ht.	Avg. ht.	Avg. dia.	Avg. ht.	Avg. dia.	Avg. ht.	Avg. dia.
Cedrus deodara (69 trees)	1	8.0′	4.5′	.4″	10.9′	1.4″	23.6′	5.2″
Average increase	1	....	—3.5′	...	6.4′	1.0″	12.7′	3.8″
Libocedrus decurrens (53 trees)	1	11.0′	11.7′	3.1″	17.4′	6.4″	26.8′	10.3″
Average increase	1	....	.7′	...	5.7′	3.3″	9.4′	3.9″
Pinus coulteri (42 trees)	1	14.0′	17.7′	6.1″	25.1′	9.2″	35.7′	13.5″
Average increase	1	....	3.7′	...	7.4′	3.1″	10.6′	4.3″
Pinus jeffreyi (43 trees)	1	6.0′	10.2′	2.4″	15.6′	4.9″	25.5′	7.2″
Average increase	1	....	4.2′	...	5.4′	2.5″	9.9′	2.3″
Cedrus deodara (18 trees)	2	4.0′	7.6′	1.1″	13.4′	3.2″	26.2′	7.2″
Average increase	2	....	3.6′	...	5.8′	2.1″	12.8′	4.0″
Libocedrus decurrens (3 trees)	2	4.0′	8.8′	2.5″	13.7′	5.3″	25.3′	11.3″
Average increase	2	....	4.8′	...	4.9′	2.8″	11.6′	6.0″
Pinus coulteri (16 trees)	2	11.0′	15.8′	7.8″	22.6′	12.1″	33.3′	18.4″
Average increase	2	....	4.8′	...	6.8′	4.3″	10.7′	6.3″
Pinus jeffreyi (11 trees)	2	10.0′	8.0′	2.0″	12.5′	4.8″	23.3′	9.6″
Average increase	2	....	—2.0′	...	4.5′	2.8″	10.8′	4.8″

Note: Diameter was taken at 4½ feet from ground. All of the above species have produced seed containers but no fertile seed has been recovered to date.

It is 35 years since this experiment was first started and a critical examination of the results obtained is now in order. Average growth made by the species listed

compares favorably with growth made by the same species under optimum conditions in their natural habitats.

From the results obtained it would appear that Forester Hosmer's experiment has proved that valuable timber trees will grow on the upper slopes of the higher mountains of the Territory. As to whether timber production will ultimately prove economical it is difficult to say.

Insects Carried in Transpacific Airplanes

A Review of Quarantine Work Prior to December 7, 1941

By C. E. Pemberton

Transpacific airplane service, with Honolulu one of the principal ports of call, has, in point of time, brought Hawaii close to tropical lands densely populated with many thousands of species of insects not in the Islands today. Quantities of these could live in the Territory and be injurious, and many could ruin our important agricultural crops or seriously affect human health. A brief historical account is given of the efforts made to block this constant menace and to emphasize the magnitude of the problem.

During March 1936 the Pan American Airways inaugurated regular transpacific airplane service between San Francisco and Manila with stops at Honolulu (Pearl City), Midway, Wake, and Guam. These flights continued through November 1941 and during the latter half of this period Hongkong was included in the itinerary. In addition to this route the Pan American Airways expanded their business early in July 1940 to include regular flights between San Francisco and New Zealand, via Honolulu, Canton Island, New Caledonia, and later Fiji. An average of three to four planes made a round trip from San Francisco over one or the other routes monthly, with stops both ways at each point mentioned in their line of travel.

Beginning on March 6, 1936 and continuing until the outbreak of the present war every plane, without exception, that stopped at Pearl City was boarded by a representative of the Anti-mosquito Control Committee, Chamber of Commerce of Honolulu, or, in 1941, an inspector of the U. S. Public Health Service, to search for and collect all insects, dead or alive, occurring in these planes. Inspectors were permitted to enter the planes prior to the release of the passengers, crew, and baggage and a hasty search was first made for living insects after which a more leisurely inspection was made for dead specimens. In this work there was close cooperation with U. S. Customs officers and plant inspectors of the Territorial Board of Agriculture and Forestry, who had access to passengers' baggage and freight which had been removed from the planes at the airport office. The Pan American Airways Company also cooperated freely.

To comply with the requirements of the U. S. Public Health Service, especially with respect to the transport of living mosquitoes, these planes were sprayed with pyrethrum extract (the normal "Flit" of the time) shortly before landing at each port and also prior to departure at all stations where they stopped. This was a duty assumed by Pan American operatives on each plane.

All insects collected at the Pearl City port, from the date of the first inspection until the beginning of the war, were submitted to the entomologists of the Hawaiian Sugar Planters' Experiment Station for identification.

As the work progressed it became evident to the entomologists that the risk of new insect pests gaining entrance to Hawaii existed in fact. Since the planes came from, or stopped at, regions where serious insect pests of sugar cane occurred which

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were not in the Hawaiian Islands, Dr. H. L. Lyon, Director of the Experiment Station, H.S.P.A., proposed the establishment by the Hawaiian Sugar Planters' Association of a quarantine station at Midway Island and later at Canton Island. This met with the full approval of the Pan American Airways Company and all others concerned. Accordingly, on November 25, 1936, the H.S.P.A. sent an entomologist to Midway. His principal assignment was to inspect and spray all planes immediately upon arrival. All insects, dead or alive, were collected and each month sent to the Experiment Station entomologists in Honolulu for identification. The planes were again inspected before departure from Midway. On April 16, 1940, with the inauguration of regular Pan American service to New Zealand, a similar station was established on Canton Island and the H.S.P.A. maintained an entomologist there also for the same type of work. The salaries of these men were paid by the Hawaiian Sugar Planters' Association, and the Pan American Airways Company cooperated in all necessary ways by furnishing board and lodging, transportation, etc. During the entire period under discussion not a single plane stopped at either Midway or Canton without attention by an H.S.P.A. entomologist. When an employee was at any time relieved of duty because of resignation, vacation, or other cause, entomologists on the regular staff of the Experiment Station at Honolulu were available to fill the gap until the special men for the Canton and Midway stations were replaced or had returned to duty. This happened several times and F. X. Williams, R. H. Van Zwaluwenburg or F. A. Bianchi kept the position filled on one or the other island each time such an emergency occurred.

It is of interest that planes from Honolulu, enroute to the south and west were also treated at Canton and Midway as a means of protection to outside islands and countries against pests in Hawaii not already in those regions.

Canton and Midway Islands thus became, in a sense, insect filters through which all planes passed before reaching Honolulu and later California. This work supplied a definite safeguard to Hawaii and the mainland against oriental and South-Sea pests dangerous to agriculture, horticulture, ornamental plants, and the health of man and domestic animals. It is the ideal form of quarantine since both Midway and Canton Islands are small coral islets with an extremely limited fauna and flora.

The record of insects taken from planes at Honolulu, Midway, and Canton is one of definite reference value, since it tells what is entering the planes at the various ports, and to what extent living forms are transported from one country to another. The great development of air transport over the Pacific since the beginning of the war has increased tremendously the number of insects carried to Honolulu from far distant places. The task of identifying these insects by the H.S.P.A. entomologists continues and the record has grown to imposing proportions. The following summary covers the record from March 6, 1936 to the end of November 1941. Though the quantity of material taken from planes since the war began greatly exceeds the collections from 1936 through 1941, the record for individual planes today remains approximately the same as that for pre-war planes.

During 1941 a number of the planes cited below were listed by the inspectors as "Bombers."

PLANES OUTWARD BOUND
March 19, 1936 to December 3, 1941

No. Planes Arriving at Honolulu from California	321
No. Insects Removed and Identified	1,367
No. Insects Found Alive	137
No. Mosquitoes Found in Planes	88
No. Mosquitoes Alive	7

RECORDS OF SPECIAL INTEREST

Anopheles pseudopunctipennis: A living female of this mosquito was taken from a plane listed as a "Bomber" on October 21, 1941. In Herms' "Medical Entomology" it is listed as an important vector of malaria in parts of South and Central America and Mexico. The mosquito occurs throughout California according to Herms but is of no consequence in California as a carrier of malaria.

Culex pipiens: A mosquito not known in the Hawaiian Islands. A total of 40 was taken from the planes arriving at Honolulu during this period, five of which were alive.

Theobaldia incidens: This mosquito was taken from planes on four occasions, a single specimen each time and in one case the individual was alive. This is a common domestic species in California but does not occur in Hawaii.

Culex tarsalis: On two occasions a single individual was taken from a plane, both being dead. This mosquito is not in Hawaii.

Pulex irritans: This common flea was taken from planes alive several times. This is of interest only to the extent that sprays evidently do not normally reach or kill them in planes.

Diabrotica soror: Three times during the period under discussion this notorious defoliator of many kinds of plants was taken from planes and in one case it was found alive. This beetle does not occur in Hawaii.

Glyptina cerina: Known as the potato flea beetle and not in Hawaii. A living specimen was taken from a plane on November 9, 1941.

Flies representing many families occurred most frequently in the planes.

PLANES HOMEWARD BOUND
March 19, 1936 to December 3, 1941

No. Planes Arriving at Honolulu from Hongkong or Manila via Guam, Wake, and Midway Islands, or from New Zealand via New Caledonia, Fiji, and Canton Island	301
No. Insects Removed at Canton, Midway, and Honolulu and Identified	10,081
No. Insects Found Alive	2,067
No. Mosquitoes Found Dead	207
No. Mosquitoes Found Alive (*Culex quinquefasciatus*)	4

Note: In the above total of 2,067 insects found alive, all but 228 were detected and removed from the planes by inspectors stationed at Canton and Midway Islands. Of the 228 taken alive from planes after arrival at Honolulu, 206 of these were insects common in Hawaii, many of which could have entered the planes after arrival at the Hawaiian port while inspection was underway. Many of these were common flies and 88 of them were ants which could be sufficiently concealed in lunch packets and other baggage to escape spray treatment. Thus during the five and one half years of operation of the Midway and Canton Island insect quarantine work, only 22 living insects not known in Hawaii were found in planes arriving at Honolulu from the South or the Orient.

Records of Special Interest

Aedes vigilax and *Culex sitiens:* These two mosquitoes have been taken dead from planes a number of times. They breed in brackish water. The former is a vicious biter. Neither species occurs in Hawaii.

Anopheles litoralis: Though not considered a vector of malaria in the Philippines, this mosquito has been found dead in planes upon their arrival at Midway several times. The mosquito breeds in brackish water. Not in Hawaii.

Aedes vexans: This mosquito has been found dead in planes a number of times. Being a vicious day biter, with a wide distribution in the tropics, it is fortunate that it has not become established in Hawaii.

Anomala sulcatula: This beetle has reached Midway alive in planes from Guam. It is a member of a highly undesirable genus of beetles whose grubs are destructive to plant roots.

Prodenia litura: A moth occurring around the tropic world but not in Hawaii. The caterpillars of this insect are highly destructive to a large number of economic plants, including banana, taro, cotton, sweet potato, tomato, cabbage, lettuce, etc. It has been taken both alive and dead from planes several times.

Nephotettix apicalis: A pest of rice. Large numbers of this night-flying leafhopper have been taken from planes from the Philippines and Guam. They have been found alive in planes arriving at Midway. Not in Hawaii, nor in California where the rice industry is a large one.

As in the case of the outward-bound planes, a large proportion of the insects taken from planes at Midway, Canton, or Honolulu was flies.

Weed-spray Studies—II*

By R. J. Borden

A follow-up of the studies in weed control, which were reported in *The Hawaiian Planters' Record,* 48: 21–29, 1944, has confirmed some of the earlier results and added a few more which are presented in the accompanying set of photographs with a few brief comments.

Because the earlier study had indicated a satisfactory kill of "wire grass" (*Eleusine indica*) at two, four, six, and eight weeks of age when "Conc. 40" was used in a 1-to-20 dilution, but an unsatisfactory kill when the dilution was 1-to-80, we were concerned with finding whether an intermediate dilution might be satisfactory. Also, because a difference of opinion existed as to the relative difficulty in controlling wire grass with "Conc. 40" as compared with "kukaipuaa" (*Digitaria spp.*), both of these weeds were included.

The treatments consisted of "Conc. 40" in dilutions of both 1-to-20 and 1-to-40 sprayed so as to thoroughly wet the foliage which had developed by the second, the fourth, and the sixth week after the weed seeds were started. Fig. 1 shows the amounts of growth for both grasses at the time the herbicide was applied.

The effects from spraying were definite and quite rapid (less than 24 hours), especially where the 1-to-20 dilution had been used and on the younger weed growth. To determine the completeness of the kill, however, the flats carrying the weeds were given good growing conditions for two more weeks before the final photographs and counts for the percentage of kill were made. Thus in Figs. 2 and 3 we have pictures of a representative flat of each treatment, taken two weeks after the applications of herbicide had been made.

The kill of wire grass (Fig. 2) by the 1-to-20 dilution was 100 per cent at all three stages of growth. With the weaker 1-to-40 dilution, however, the kill was only 64 per cent on the older six-week growth, 70 per cent on the four-week-old growth, and 75 per cent on the young two-week-old weeds.

On the kukaipuaa (Fig. 3) the 1-to-20 dilution was also 100 per cent effective at all three growth stages, whereas the kill from the 1-to-40 dilution was only 45 per cent on the older weeds, 80 per cent on the four-week-old growth, but 96 per cent on the youngest weeds.

The differences in the kill of these two weed species by the 1-to-40 dilution are of interest. Apparently the younger growth of kukaipuaa was more susceptible than the corresponding growth of wire grass, whereas it was somewhat more difficult to get a satisfactory kill of the six-week-old kukaipuaa than of wire grass of the same age. This is perhaps due to the fact that the more recumbent growth habit of the kukaipuaa, as it gets older, makes it very difficult to penetrate the leafy mass with the spray solution, whereas the more erect stems of the wire grass can be more completely wetted.

With both weed species some individual plant tolerance to the more dilute herbicide as used was again found. When the plants were being sprayed, special care

* Project A 105—No. 83.2.

was taken to see that all visible foliage was thoroughly wetted. In spite of this precaution some individual plants were not killed.

Records of the amounts of spray solution that were required to wet adequately the foliage show that the four-week-old weed growth required four times the quantity needed by the two-week-old weeds, and that the six-week-old weeds required eight times as much as the young two-week-old plants.

These results lead us to re-emphasize the fact that a delay in spraying results in inefficiency. Early spraying gives the best control and uses the least material, for once the weeds have formed more than four or five leaves, it will be difficult to kill them except with more concentrated herbicides. So, when spraying is delayed, not only must the concentration of the herbicide be stepped up, but the total quantity used must be increased, and both such increases involve a greater likelihood of injury to the cane crop itself.

Fig. 1. Weed growth at time of spraying:
I—6-week-old growth. II—4-week-old growth. III—2-week-old growth.
Upper: Wire grass. Lower: Kukaipuaa.

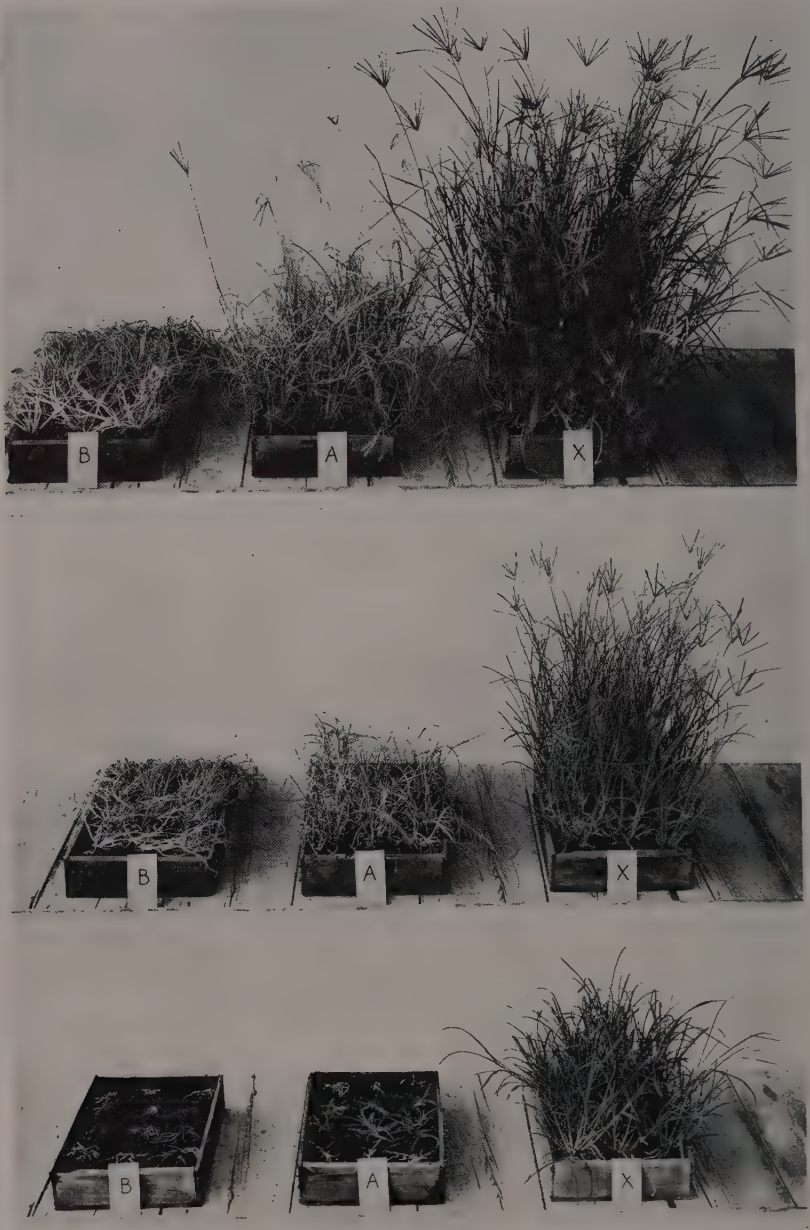

Fig. 2. Two weeks after spraying wire grass:
X—With tap water only.
A—With "Conc. 40" at 1-to-40 dilution.
B—With "Conc. 40" at 1-to-20 dilution.
Age when sprayed: Upper—6 weeks; center—4 weeks; lower—2 weeks.

Fig. 3. Two weeks after spraying kukaipuaa:
X—With tap water only.
A—With "Conc. 40" at 1-to-40 dilution.
B—With "Conc. 40" at 1-to-20 dilution.
Age when sprayed: Upper—6 weeks; center—4 weeks; lower—2 weeks.

Chemical Control of Hardy Weed Grasses

(A Discussion)

By Francis E. Hance

Tough, wiry grasses are supplanting the more rapidly destroyed succulents and annuals in many Hawaiian cane fields. A discussion is presented suggesting a means of meeting this situation in the current research devoted to the weeding problem.

Over a period of years a continuous program of chemical spray treatment of sugar cane field weeds results in the disappearance of succulent, annual, broad-leafed weeds, and the survival of the more resistant grasses.

The present Hawaiian practice of weed control does and will destroy, for a limited time, most all above-ground weed growth regardless of age, *provided the weeds are actually wetted.*

Our spraying practice destroys most of the tender succulents and all of the bushy annuals. Going down with them temporarily, as burned blades, are the predominating fractions of most cane field weeds—grasses. An area adequately sprayed at this point gives the appearance of a chemical weeding job that has been very well done. Actually the job is not well done because the readily destroyed succulents and annuals have been removed for the season and in the course of a few weeks their place will be taken by the oncoming grasses which will be found budding vigorously and rapidly from the soil side areas of every "dead" grass crown in the field. Such a weeding practice is but a compromise because it expands the grassy coverage and encourages the growth of the very weed types which are the most difficult to eradicate.

Even were labor available to substitute hoeing for the toxic chemical sprays the net result would be essentially the same.

Agricultural literature describes chemical weeding operations on the mainland which frequently appear promising and encouraging. Circulars and advertisements issued by chemical herbicide manufacturers often give glowing accounts of phenomenally effective spray chemicals. In almost all cases such claims are reasonably correct and fittingly proper when assessed against field conditions, the type of weeds, and among the crops where they are used. In running down a promising lead we frequently find that a given herbicide will, at low concentration and in one application, utterly destroy all the weeds in a field of grain or vegetables and scarcely or not at all injure the main crop. As a rule the herbicide will be a non-poisonous compound and comparatively easy to procure. Time after time it develops, at this point, that the weeds referred to are entirely of the broad-leafed variety (hence readily destroyed) and the crop not injured by the herbicide is a member of the grass family (pasture, wheat, barley, corn, etc.). Obviously we get little to bolster our weeding program from a herbicide of this character. However, this is not always the case.

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A. S. Crafts and H. G. Reiber (2), for instance, in discussing the toxicity of certain petroleum oils to plant life differentiate between the prompt chemical effect of herbicides upon plant tissues with which they come in contact and the slower, penetrating effect of certain oils, or emulsions of oils, beyond the points of contact and extending, in the cases of some grasses, to the region of the crown and even below that part of the grass crown at the soil surface. The penetrating effect they describe, if found sufficiently lethal toward Hawaiian grasses, suggests a lead which should be thoroughly investigated.

In another discussion Crafts (3) describes experimental studies in which oil-soluble amendments were incorporated with petroleum oils in order to fortify them to the point where the treated oil would remain effective even under high dilution or as an emulsion with water. He found three outstanding fortifying agents: dinitro ortho cresol, pentachlorphenol, and dinitro ortho secondary butyl phenol.

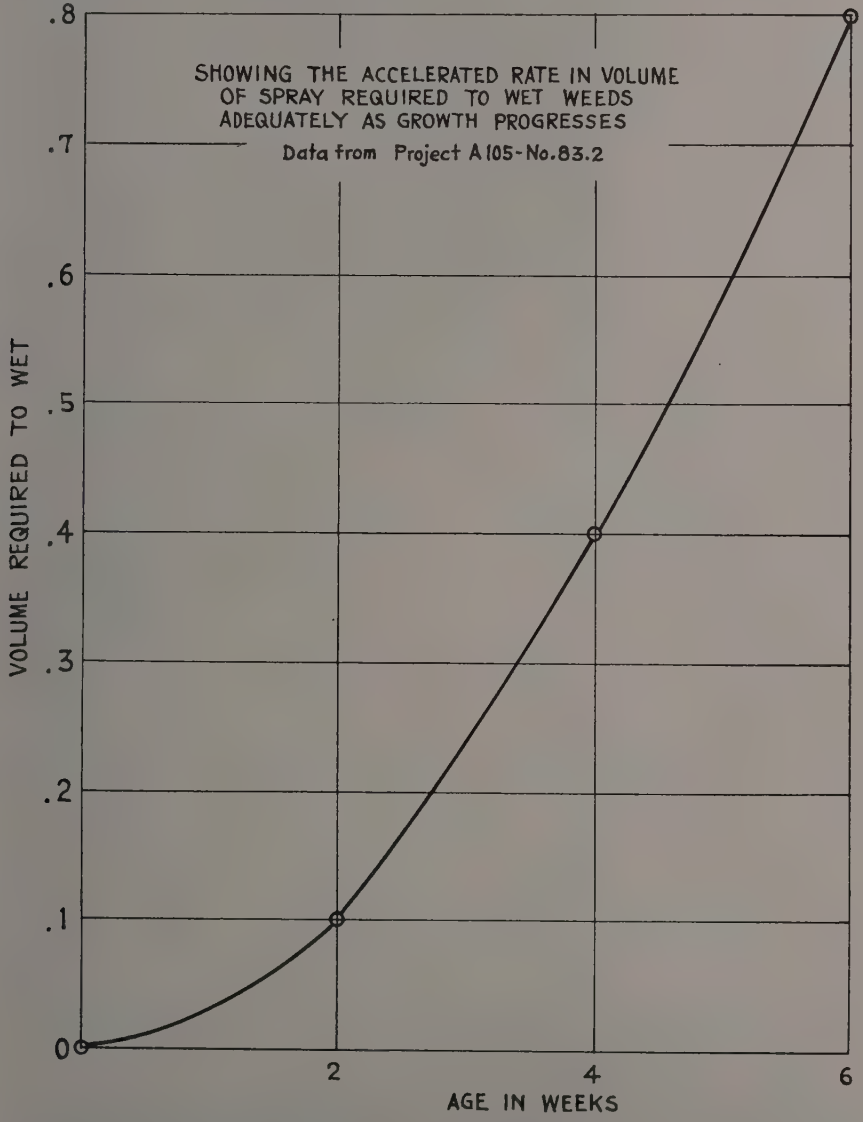
Using a formula containing ½ per cent pentachlorphenol in a six per cent Diesel-oil emulsion he secured rather encouraging results. He states that this formula proved sufficiently toxic to coarser grasses to provide adequate fire strips along highways. *When applied in sufficient volume to cover the vegetation completely* it killed everything except wild oats and barley in the early heading stages. It did kill crowns and basal portions of the stems which it affected so that the plants died completely in a period of 20 days. However, barley plants survived two sprayings of this mixture.

If Crafts' discussion has been correctly understood it appears that increased toxicity secured by fortifying oil emulsion grass sprays is not desirable after all. He suggests that ⅛ per cent dinitro secondary butyl phenol will replace the ½ per cent pentachlorphenol in the above formula, although, he adds further that by increasing the butyl phenol compound to ¼ per cent or more a more toxic mixture may be obtained *but even this increased toxicity may not be of any avail in killing large vigorous grass plants.*

We gather from Crafts' description of his research studies that, rather than depend on a highly toxic amendment to a contact herbicide, a superior effect may be realized on grasses by utilizing the slower penetrating toxicity of certain petroleum fuel oils, and thus reach the stems and even the crowns to a distance of several inches from the portion of the plant actually sprayed. He cites the effectiveness of water-and-oil emulsions as a substitute for straight oil applications, but notes the disadvantage of an ordinary emulsion of this type which necessitates providing the spray tank with an agitator. He does not lean entirely aside from aqueous solutions of herbicides, however, for he reports satisfactory control of grasses using ½ per cent of the ammonium salt of dinitro ortho secondary butyl phenol with an effective wetting agent.

In an article appearing directly ahead of this paper, R. J. Borden (1) reports that, when a measurement was made of the requisite volume of spray solution required to wet adequately the weed foliage in an experimental study, it was found that a volume sufficient to cover a two-week-old grass growth had to be increased four times for an identical stand of the same type of grass at double this age, and eight times the two weeks volume under comparable conditions upon a stand at triple the two weeks age. In a graph, Borden's data illustrate in a spectacular manner the rapidly accelerating rate at which the volume of spray solution must

be increased to keep pace with advancing weed growth beyond the tender shoot stage. The implications are obvious as to efficiency of lethal dosage and economy of labor, equipment and chemicals. The graph is shown herein.



Facts accruing from observations in the field and in the literature may be summarized as follows:

1. Our presently employed spray solutions are "contact" herbicides.
2. A contact spray destroys only that portion of the weed which it wets.
3. The time to spray is immediately following the appearance of young, tender, weed growth.

4. Spray solution striking bare soil will not destroy germinating weed seeds directly beneath the soil surface, nor the young plants which will follow later.

5. Wetting agents or spreaders are essential in most spray solutions to insure uniform wetting of grass blades or waxy leaf surfaces.

6. Combinations of the H.S.P.A. Activator and sodium chlorate in water *do not* require the addition of a wetting agent.

7. Increasing the concentration of lethal substance in a contact spray above that just required to destroy above-ground portions of the plant will not in any manner contribute to a better or more lasting kill, nor will it ordinarily reach the root systems of tough grasses or the embryo growing points just under the crown.

8. Herbicide compounds used extensively on the mainland for destroying broad-leafed weeds and annuals in grain fields—without damage to the main crop—are of little value on Hawaiian cane lands.

Further research studies in weed control by the Chemistry department of the Experiment Station are planned to be conducted somewhat as follows:

1. The combining of low concentrations of our present lethal agents with graded amounts of penetrating oils (described elsewhere) in an effort to destroy or weaken above-ground portions of grasses and at the same time reach the stem and under-crown area with the penetrant oil plus the lethal substance combined with it.

2. The double objective in No. 1 implies a single spray application of a fairly stable emulsion *on young grass*. It is conceivable that on older grasses additional applications of the emulsions must be made if the stems and crowns are to be reached. These points are to be studied.

3. Explore as fully as possible all available oily penetrants which may prove effective in controlling grasses and which may be applied as a spray with existing equipment.

4. Determine by field trial the value of newly proposed "non-poisonous" herbicides under Hawaiian conditions.

5. Endeavor to develop a type of oil-water emulsion which will not break for an hour or longer and which will carry other essential constituents toxic to hardy grasses. This objective, if realized, will eliminate the complication of agitation of spray emulsion during its application.

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Nitrogen Efficiency

By R. J. Borden

Under conditions of all-year-round growth, where crops of sugar cane are being started almost every month of the year, we often find nitrogen fertilizer applications being made (weather permitting) without serious regard to the so-called seasonal conditions that are likely to prevail immediately thereafter. These conditions apparently can have a considerable influence on the amount of nitrogen absorbed and its subsequent use by the crop.

The results which are here discussed show that a more complete uptake of nitrogen and greater yields by an indicator crop have followed nitrogen applications that were made in May and August than from similar amounts applied in February or in November. Thus the efficiency of the nitrogen fertilization has been definitely influenced by as yet unidentified seasonal effects.

Although the sugar cane areas in Hawaii do not have extreme ranges in climatic conditions, there are some differences in temperature and sunshine, and in wind, humidity and rainfall intensity which probably have their combined direct and indirect effects on yields, and one of our previous studies* has already definitely established the dominating effect of climate upon cane and sugar yields. Hence, inasmuch as the major changes or differences in climate form the basis for the divisions of the year into seasons, we would expect the seasonal differences to also have a large influence on yields.

The Plan:

In an effort to find the seasonal effects on the response to be obtained from nitrogen applications, we have completed the first five years of a study† with this objective. For this study we prepared a well-mixed stock of a Manoa soil in October 1938 and on the first of November, February, May, and August during each year since this date we have planted a series of 24 Mitscherlich pots with an indicator crop (*Panicum barbinode*). As far as possible each series has been grown under as nearly identical conditions for development as could be provided, except for the following eight differentials in nitrogen fertilization which were added to the soil as ammonium nitrate at the time of planting:

No. 1—Control, no N.	No. 5—1.1 gms. N/pot
No. 2—0.275 gm. N/pot	No. 6—1.375 gms. N/pot
No. 3—0.55 gm. N/pot	No. 7—1.65 gms. N/pot
No. 4—0.825 gm. N/pot	No. 8—2.2 gms. N/pot

Each indicator crop has been harvested at 90 days after planting and we have secured at each harvest (1) the total dry weight from each of the three replicated pots of each treatment, and (2) the total nitrogen content from a composited sample

* A 105—No. 43.

† A 105—No. 104.01.

of these dry weights. From these data we have calculated the differences between the total grams of nitrogen as found in the crop from the control (no N), and the total in each crop from each of the seven treatments which received the nitrogen fertilizer; these differences have then been expressed in terms of the per cent of nitrogen added which was recovered.

Effect on Yields:

The data which have been secured have been studied to find the effect, on the total dry weights harvested, that was produced by each of three main factors, namely: (1) *amounts* of nitrogen applied, (2) *year* during which crop was grown, and (3) *season** of year in which the growth took place and by their first-order interactions. An analysis of variance has established the degree of significance of these effects, and we have identified a dominant and independent effect for each of the three main factors over any of their interactions. Hence we can limit our summary and discussion to these main effects which are shown in Table 1.

TABLE I
SUMMARY OF 3 MAIN EFFECTS ON YIELDS
Grams Total Dry Weight Harvested

1—From amounts supplied (for all years and seasons)

Gms. N supplied	Avg. gms. dry wt.
0	47
.275	119
.55	183
.825	239
1.1	267
1.375	295
1.65	319
2.2	337
M.d.r.	9

2—In different years (for all amounts and seasons)

Year	Avg. gms. dry wt.
1939	221
1940	214
1941	208
1942	229
1943	257
M.d.r.	7

3—In different seasons (for all amounts and years)

Season	Avg. gms. dry wt.
Winter	152
Spring	203
Summer	275
Fall	273
M.d.r.	6

M.d.r. = minimum difference required for odds of 19 to 1.

Increasing the amounts of nitrogen has resulted in the increases in dry weights which were more or less expected. Yields from the different years showed some fluctuation but the low average for 1941 was only 19 per cent less than the high average for 1943. But our chief interest in these summaries lies in the effects produced by the different seasons, for it is doubtful if their relative effects on yields have heretofore been as adequately established. Thus we find that yields from the indicator crops which were grown during the winter and spring were only 55 and 74 per cent respectively of the averaged summer-fall crops in spite of the fact that a uniform and comparable treatment was given for five years of cropping in all seasons.

A good idea of the specific effects from different seasons upon the dry weights as harvested from the different nitrogen treatments may be obtained from Fig. 1.

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* For convenience, the following seasonal identities have been used:
Winter—for the crops started November 1 and grown during the next 90 days.
Spring—for the crops started February 1 and grown during the next 90 days.
Summer—for the crops started May 1 and grown during the next 90 days.
Fall—for the crops started August 1 and grown during the next 90 days.

Here we note: (1) The similarity of the yields which resulted from identical amounts of nitrogen supplied for the summer- and fall-grown crops, and their general level above the average for all seasons; (2) a curve of dry weights from spring-grown crops which is definitely below this average; and (3) still lower levels for the yields from the winter crop.

Nitrogen Efficiency:

The figures in Table II are those for the average grams of dry weight produced per gram of nitrogen supplied—a good measure of nitrogen efficiency.

TABLE II
EFFICIENCY OF APPLIED NITROGEN

Grams N applied	Grams dry wt. per gram N				Average for amounts applied
	Winter	Spring	Summer	Fall	
.275	305	382	513	535	409
.55	229	295	398	411	333
.825	195	256	354	356	290
1.1	164	220	297	289	243
1.375	144	195	264	255	215
1.65	129	175	235	233	193
2.2	99	142	190	182	153
Average of seasons	181	238	322	323	

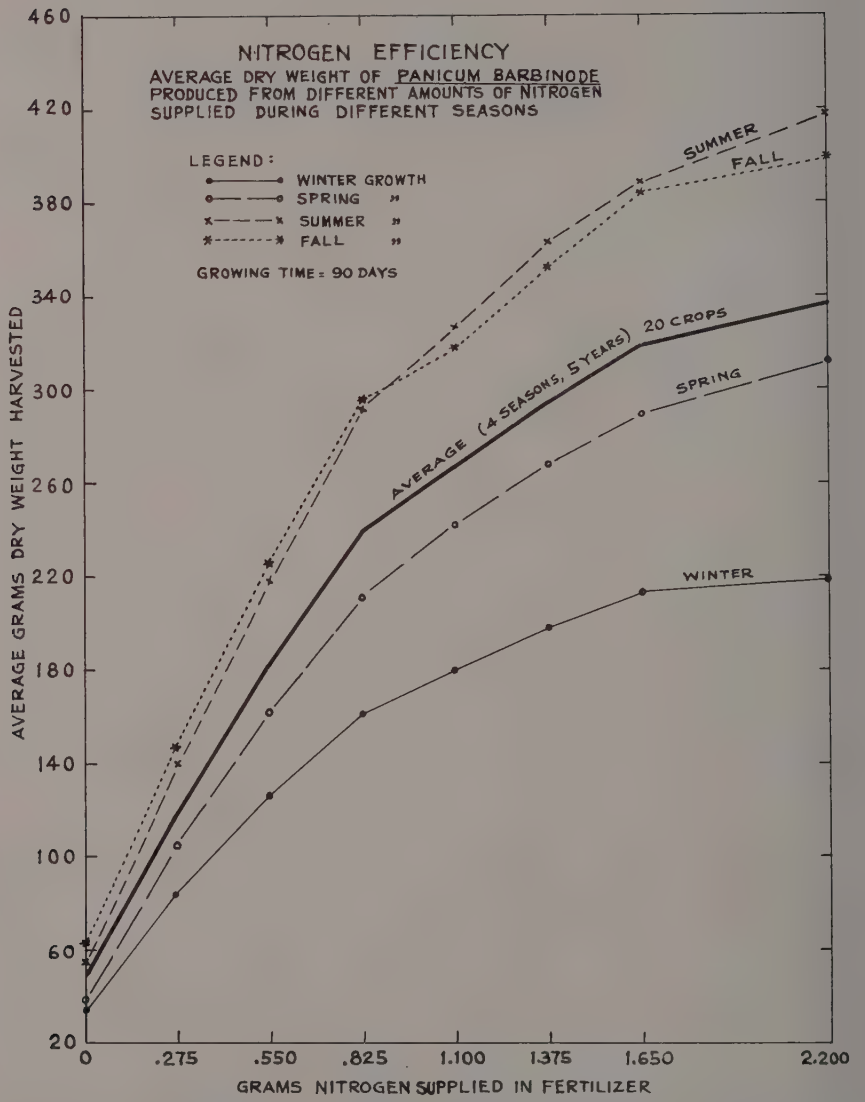
For each additional amount of nitrogen supplied there is the corresponding decrease in efficiency that is usually associated with all growth factors, *i.e.*, the law of diminishing returns is operative; this is true regardless of the season during which the crop was grown.

Differences in seasonal effects are quite clear. Thus one gram of nitrogen supplied for summer and fall growth produced an average of 322–323 grams of dry weight as compared with an average of 238 grams from spring growth, and of only 181 grams of winter growth.

A few examples from the graphs on Fig. 1 will further emphasize the difference in the nitrogen efficiency that was obtained during different seasons. For instance: an application of 0.55 gram N produced an average yield from 20 crops of 183 grams. Reference to the several curves and their axes in Fig. 1 will show that an equivalent yield would be expected from crops grown in summer and fall when supplied with only 0.41 gram N (25 per cent less N) but that an equivalent yield from spring-grown crops would probably need 0.69 gram of N (25 per cent more) and, furthermore, that this average 0.55-gram application would need to be more than doubled to produce an equivalent yield in winter.

From another viewpoint the curves in Fig. 1 show that 1.1 grams N have produced an average of 323 grams of total dry weight from summer and fall applications. This same amount of nitrogen applied in spring was able to produce only 242 grams, and only 180 grams when it was supplied in winter. Thus, if it were deemed necessary to provide 1.1 grams N in summer and fall in order to get a desired yield, this amount would be excessive and wasteful for applications in spring and winter when even double the amount (2.2 grams) has failed to produce an equivalent dry weight.

Still another angle to emphasize this point can be shown from Fig. 1. The maximum yield secured from the winter crop was 218 grams, and this was the result



from the 2.2-gram application of nitrogen. This same amount of dry weight could have been produced by approximately 0.9 gram N or 60 per cent less nitrogen applied in the spring, and by approximately 0.5 gram N or 80 per cent less nitrogen applied in the summer and fall.

Thus the evidence seems quite clear that there will be differences in nitrogen efficiency, *i.e.*, its ability to affect yields, which will be due to the differences in the seasonal conditions that prevail during the next few months after the nitrogen fertilizer is supplied. That this difference in efficiency is in turn due to a difference in the probable nitrogen uptake and recovery by the growing crop is strongly suggested by the subsequent discussion.

Nitrogen Recovery:

The nitrogen recovery figures reported hereafter have reference to the total nitrogen found in the total vegetative growth (except roots*) produced by each treatment in a period of 90 days. Previous studies have shown that 90 days are adequate for the complete exhaustion of applied nitrogen from soil potted and cropped as in the present study. Moreover, an analysis of this soil showed an absence of available nitrogen (by R.C.M.) at harvest, and subsequently the total amount of available nitrogen found was never more than 0.0008 per cent. Thus we can assume a reasonably complete depletion of the available nitrogen from the cropped soils. Furthermore, losses of nitrogen by leaching were avoided by the use of drainage pans and the return of all leachates when the pots were irrigated. So it seems quite safe to imply that the percentage nitrogen recoveries that we have recorded at least represent the trends from the effects indicated.

An analysis of variance of the nitrogen recovery figures shows: (1) a significant and independent effect from the different amounts of nitrogen supplied in the fertilizer upon its subsequent recovery in the crop grown; (2) an effect of the year in which the crops were grown, which effect was however differently influenced by the season of the year concerned; and (3) a highly significant and wholly independent effect of the four seasons during which the crops developed. Interactions between amounts and years, and between amounts and seasons were not significant.

A summary of the three main effects and of their only significant interaction (years X seasons) is given in Table III.

TABLE III

SUMMARY OF 3 MAIN EFFECTS ON NITROGEN RECOVERY

Percentage of Nitrogen Added That Was Recovered

1—From amounts supplied		2—In different years		3—In different seasons	
Gms. N supplied	Avg. % recovered	Years	Avg. % recovered	Seasons	Avg. % recovered
.275	78.2	1939	80.6	Winter	64.4
.55	79.8	1940	84.2	Spring	76.7
.825	81.9	1941	74.8	Summer	92.0
1.1	81.3	1942	79.0	Fall	88.3
1.375	81.5	1943	83.2		
1.65	83.1			M.d.r.	2.8
2.2	76.8	M.d.r.	3.1		
M.d.r.	3.7				

SUMMARY OF INTERACTION BETWEEN YEARS AND SEASONS

Average Percentage of Nitrogen Added That Was Recovered

	Years				
Season	1939	1940	1941	1942	1943
Winter	66.0	64.0	64.3	59.8	67.8
Spring	75.6	82.8	76.3	71.8	77.3
Summer	90.9	100.4*	79.6	92.5	96.8
Fall	90.1	89.6	79.2	91.9	90.9

M.d.r. = 6.3 *SE = ±2.3

* While we regret the omission of the roots, it is not believed that the relationships involved would be significantly different from those found for the above-ground parts that were harvested and analyzed, for the amounts of dry weight of roots and of the nitrogen therein would be expected to reflect the variations in amounts of nitrogen supplied, and in the effect of years and seasons quite similarly to the top growth. Thus the inclusion of the roots would have increased the actual totals but probably made little difference in the relationships between the several effects that were studied.

The percentage of nitrogen recovered from the different amounts supplied, which were not differentially influenced by the year or season in which the crops were grown, does not vary to any great extent until the highest amount is encountered; this 2.2-gram application shows a somewhat reduced recovery, and thus lends support to previous studies which have also shown lower percentages of nitrogen recovered from the higher nitrogen applications.

Recoveries of nitrogen in the crops grown in 1940 and in 1943 were the highest of the five-year period and were quite similar. However, although the spring and summer crops in 1940 were able to pick up more nitrogen than those in these same seasons of 1939 and 1942, this was not true for the fall and winter crops of these same years. And although 1940 recoveries were in general higher than those of 1941, this was not true for the winter seasons in these two years. The winter crop of 1943 showed a higher recovery than that of 1942 but during the other three seasons of these two years the differences were not significant ones. Comparing the crops of 1943 with 1941, we find higher recoveries for the 1943 crops during the summer and fall only. Comparisons of 1943 with 1939 and 1940 show very similar seasonal recoveries of the applied nitrogen.

The most significant information, however, is that the nitrogen uptake and thence its recovery in the crops that were grown in the summer seasons was more complete than from the fall-grown crops; that recovery from the crops grown in the fall was in turn greater than from those grown in spring; and furthermore that more nitrogen was recovered in the spring-grown crops than in those grown during the winter. These findings point quite definitely to the fact that nitrogen applied for growth during the summer has the best chance of being most fully taken up by the growing crop, and hence it should be more efficient than nitrogen applied at other seasons. Even without the possibility of losses by leaching, the probable recovery of nitrogen from the winter and spring applications seems too low to guarantee full efficiency therefrom.

From these facts, which have been secured from carefully controlled crops of panicum grass, we can perhaps postulate that a crop of sugar cane should get a higher efficiency from summer than from spring applications of nitrogen. Furthermore, if these percentage recovery figures from panicum grass in the different seasons can be considered reasonably valid for sugar cane, we would expect that it would take an application of approximately 70 pounds of nitrogen in winter, or of 60 pounds in spring, to result in an equivalent recovery of nitrogen by the crop from only 50 pounds applied in summer or fall.

The Recent Introduction of Armyworm Parasites From Texas

By Fred A. Bianchi

Six species of parasitic wasps were introduced from Texas during 1942–1943 in an effort to obtain further control of Laphygma exempta *and other related armyworms and cutworms. Two species are known to be established already and some of the others may reasonably be expected to turn up in our fields eventually. The present article is intended to familiarize plantation men with the salient aspects in the life history of the species already established and to alert them in regard to those which have not yet appeared in our fields but may yet show up. In addition, while not intending to forecast the future value of the species concerned, the article presents historical data which should serve to facilitate such an evaluation if it is ever attempted.*

Laphygma exempta (Walker), the common armyworm of our cane fields, is of oriental origin and not found on the American continent. Some related moths, however, are of even greater importance in the mainland United States, particularly in the southern areas, than *L. exempta* is in Hawaii. Among them is *Laphygma frugiperda* (S. and A.), the fall armyworm, whose sporadic depredations are likely to extend over nearly two-thirds of the United States and which in habits and appearance is very similar to *Laphygma exempta.* Although the planters of corn or alfalfa may sometimes experience difficulty in believing the fact, this pest is known to be attacked by an imposing list of parasites, without which the depredations of the host would doubtlessly be much more serious than they are. This parasite-complex was studied principally by R. A. Vickery, Bureau of Entomology, U. S. Department of Agriculture, in the Gulf Coast District of Texas during several years beginning with 1910 (*Studies on The Fall Army Worm in the Gulf Coast District of Texas,* Technical Bulletin No. 138, U. S. Department of Agriculture), and it was his findings that led to the choice of Brownsville, Texas, as headquarters for the present writer when in 1942 it was decided to undertake the introduction of additional parasites of *Laphygma exempta* into Hawaii. Observations incidental to other work done in Guatemala in 1932–35 and in 1941 had already shown us the scarcity in Central America of hosts related to *Laphygma exempta* and the probable difficulty of obtaining the desired parasites either there or farther south, so the presence of *L. frugiperda* and its numerous enemies within the U. S. and in reach of quick transportation may be considered a piece of good fortune for the Territory.

Vickery's bulletin, which appeared in 1928, lists eleven primary parasites. To these the present writer was able to add another, a species of *Perisierola,* which was actually reared from *L. frugiperda* in the laboratory. Thus Texas offered the choice of twelve parasites, but we attempted the introduction of only six. Two of the species in Vickery's list, *Euplectrus platyhypenae* Ashmead and *Frontina archippivora* (Williston) are already items of long standing in the fauna of Hawaii, and some of the others, for one reason or another, were not considered.

Of the six species, whose introduction was attempted, two, *Apanteles marginiventris* (Cresson) and *Meteorus laphygmae* Viereck, are known to be established and this paper is intended mainly to familiarize the sugar planters with their habits and appearance. It is expected that in the course of time some or all of the other species will be recovered in the field, and as this occurs full accounts of their life histories will be published. For the present we offer only the facts of their introduction and some incidental notes which may prove of general interest.

Chelonus texanus (Cresson)

This stout and vigorous braconid resembles our own *C. blackburni* Cameron and like it is a solitary endoparasite which oviposits in the eggs of the host and develops within the body of the larvae. When parasitizing *Laphygma frugiperda* it reaches full development in caterpillars of the fourth instar and causes them to cease feeding prematurely and to form a sort of pupal cell either in the soil, in trash, or, when reared in the laboratory, within tunnels which the caterpillars are likely to gnaw out in the process of feeding on young corn plants. Within this cell the parasite completes the destruction of the caterpillar and, leaving nothing but the outer skin undevoured, constructs a tough silken cocoon from which, in a matter of one or two weeks, it emerges transformed into an adult wasp.

Vickery found *Chelonus* parasitizing 33 per cent of all the small caterpillars collected in the vicinity of Brownsville and as high as 55 per cent of the collections from other places. From these figures he concludes that *Chelonus texanus* is the most important parasite of *L. frugiperda* in the Gulf Coast States; but although it is not specifically stated in Vickery's bulletin, it can be judged from the context that his figures were obtained mainly, if not exclusively, from collections made on corn. To the present writer, whose largest collections were always obtained in the grasses of fallow or uncultivated areas, Vickery's figures seem to exaggerate greatly the overall importance of *Chelonus*. While it was always true that this parasite seemed to be of predominant importance in young caterpillars collected on corn, there were several occasions when collections of from 500 to 1,000 caterpillars from grasses yielded no *Chelonus* at all or, perhaps, at most a dozen or so among hundreds of *Apanteles* and others. Nevertheless, the importance of *Chelonus* on corn in Texas and its presence in some quantity during all seasons of the year, sometimes when other parasites were nowhere to be found, are indicative of the potential value of the species to Hawaii.

It is known that *Chelonus texanus* is able to develop successfully on *Heliothis armigera* (Hubner), *Laphygma exigua* (Hbn.), one or more species of *Prodenia,* and *Ephestia sericaria* (Scott) the Mediterranean flour moth, in addition to *Laphygma frugiperda* and *Laphygma exempta,* so it would not have been difficult to rear enough of the parasites in the Texas laboratory for shipment to Hawaii if that had been necessary; but it was not. It proved quite simple, although somewhat laborious, to obtain enough parasites from caterpillars collected on young corn. Caterpillars of the proper stages were seldom more numerous than two or three per plant and almost always had to be cut out of the leaf spindle, which involved delicate and slow manipulating of both the plant and the insect, but once out of the spindle they were easy to handle. Carried to the laboratory in screen-top cans, they were placed over a layer of sand or soil in well-ventilated boxes and there permitted to remain undis-

turbed until the majority had stopped feeding and had dug into the sand. The sand was then carefully sifted and the caterpillars, most of them by now lying quiescent within cells moulded in the sand by the wriggling of their bodies, were transferred to small pill boxes. In the pill boxes, with the caterpillars carefully cushioned on loose cotton and not more crowded than four or five to a box, the larvae of *Chelonus* continued their development and eventually, when nothing but ragged pieces of the host remained, they constructed their cocoons, using the loose cotton and the sides of the box as bases of attachment for their spinning. In the same pill boxes, crowded into ordinary mailing tubes, the parasites reached Honolulu either in the cocoon stage or as adults, depending on the time that each consignment was in transit.

Apparently even under the most favorable conditions a large proportion of *Chelonus* larvae exhaust themselves while constructing their cocoons, and no practical manner was found to prevent this from happening while our material was en route. However, out of a total of 1,444 *Chelonus* shipped from Brownsville in seven consignments more than 900 arrived in Honolulu in good shape. Some of these were liberated directly in our fields. Counting them and the progeny of the others, there was made, between June 1942 and May 1943, a total of 19 liberations, which amount-to 421 adult wasps, 300 small parasitized larvae of *Laphygma exempta,* and 250 egg masses of the same moth in which a majority of the eggs had been stung.

Neopristomerus appalachianus Viereck

This ichneumonid is apparently not of great importance in Texas. According to Vickery it was reared from *Laphygma exigua* and from one or more species of *Prodenia* but infested only 1.4 per cent of all the small caterpillars of *Laphygma frugiperda* collected in the course of Vickery's work. In our collections it was likewise scarce and no particular effort was made to reproduce the species in the laboratory or to introduce it into the Territory. Nevertheless, 65 specimens of *Neopristomerus* reached Honolulu at various times in vigorous condition and were liberated in *Laphygma*-infested fields on the islands of Kauai and Hawaii.

The life history of this species has not been worked out in detail but *Neopristomerus appalachianus* is known to be a solitary endoparasite. The present writer found it only on caterpillars of *Laphygma exigua* infesting corn and observed that these acted in a manner very similar to that of caterpillars parasitized by *Chelonus texanus, i.e.,* they stopped eating prematurely during the fourth or fifth instar and built a cell within which the parasite larva eventually finished the destruction of the host and spun a cocoon. The cocoons are made of thin, brown, paper-like material. Their upper surfaces are loosely woven and appear to be downy, and in shape they are cylindrical, about 9 mm. long and bluntly rounded at the ends. They are easily distinguished from cocoons of *Apanteles*, and with a little care it is also possible to distinguish the caterpillars parasitized by one species from those parasitized by the other. In practice, however, we avoided superfluous handling of our material by not separating the two species, so that *Neopristomerus* always arrived in Honolulu with larger consignments of *Chelonus*.

Perisierola sp.

The failure of Vickery and his collaborators to notice this active bethylid at work in the corn fields of Texas suggests that it may be a new arrival to the region. The small size, rapid movements and secretive habits of the species make it obvious that

for every wasp observed many must pass unnoticed; but even so, at times they seemed quite common. The writer saw them frequently and believes that they may be a factor of considerable weight in the control of both *Laphygma frugiperda* and *Heliothis armigera*. They were particularly noticeable on still, hot days on young corn, but they were also found on full-grown corn and in short weeds and grasses which harbored small caterpillars. One cool and dewy morning, when a field of waist-high corn was visited just at sunrise, many males were found resting singly on the upper surface of the leaves; but whether this is the usual manner of their pernoctation and whether the females practice a similar habit was not ascertained.

The writer has seen *Perisierola* wasps attacking the second and third instars of *Laphygma frugiperda* and also one or more early but undetermined instars of *Heliothis armigera*. On corn they were frequently found pulling paralyzed caterpillars from the folds of the spindle and dragging them over the leaves of the plant, but they were never actually observed in the act of stinging or ovipositing. Apparently they will not oviposit in the field until the caterpillar is finally hidden in some nook which the wasp considers safe. Since no caterpillars bearing the eggs or larvae were ever found above ground, we may assume that *Perisierola* hides its victims in the soil or trash cover before ovipositing on them.

In the laboratory oviposition occurred readily on small *Laphygma* caterpillars collected with the wasps that were dragging them. On one occasion when a wasp and a third instar caterpillar, the latter completely flaccid, were placed together in a one-half-inch tube late one day and observed early the next, five eggs had been laid overnight. These had hatched 24 hours later and within 72 hours after hatching the resulting larvae had consumed all but the cuticle of the caterpillar and had spun small, brown cocoons of paper-like consistency from which adults emerged in eight days.

The eggs are less than a millimeter long; they glisten and are pearly gray in color. In shape they are rather elongately oval and more acutely rounded at one end than the other. They are laid exteriorly on the dorsum and sides of the abdominal segments, always parallel to the longitudinal axis of the caterpillar but oriented either towards the head or the caudal end of it and apparently without discrimination as to the segment on which they are placed.

No attempt was made to rear *Perisierola* in quantity or to introduce the species into the Territory.

Meteorus laphygmae Viereck

Meteorus laphygmae is one of two species among our Texan introductions which are known to be established in the Territory. It has been recovered in two instances from Field 13 of the Oahu Sugar Company, Ltd. The first time, January 20, 1944, it was reared from a caterpillar of the beet armyworm (*Laphygma exigua*), and the second, January 26, 1944, from a caterpillar of the corn-ear worm (*Heliothis armigera*). Later, April 1944, *Meteorus* was also found well-established on the island of Hawaii. At that time, James T. Nagasako of Hawaiian Agricultural Company, Pahala, submitted for identification numerous adults and cocoons which he had collected in two fields of that plantation, in one of which liberations had been made on December 3, 1942.

Evidence that both *Laphygma exigua* and *Heliothis armigera* are attacked by *Meteorus* is of special significance, not only because it augurs a desirable reduction

in the population of the latter pest as well as the former but because it shows the ability of the parasite to spread and to perpetuate itself during the long intervals of scarcity which characterize the history of the grass armyworm in Hawaii.

Vickery found that in Texas, *Meteorus* was second in importance only to *Chelonus texanus* among the parasites of *Laphygma frugiperda*. In the present writer's experience it was found less often on corn than *Chelonus, Apanteles,* or *Rogas,* but more often than any of the others on grasses. Search of Bermuda grass lawns in the city of Brownsville seldom failed to show indications of its presence, and on several occasions isolated infestations of *Laphygma* on such lawns were apparently wiped out by this parasite alone. However, the largest collections were made on forage grasses, often waist-high and over.

Fig. 1. Adult female wasp and cocoon of *Meteorus laphygmae* Viereck. Note the long, thin thread on which the cocoon swings from the point of attachment.

The finer details of the life history of this parasite are not known but Vickery's researches have provided an outline of the facts. According to that author, *Meteorus* is far from being exclusive in its choice of host and has been reared in Texas from at least eleven species of caterpillars, of which some, *Heliothis armigera* (Hub.), *Cirphis unipuncta* (Haw.), and *Laphygma exigua* (Hbn.), are common in Hawaii and others have near relatives among us. When attacking *Laphygma*

frugiperda the small and active wasp will oviposit readily on caterpillars of the first and second instars but it refuses, in the laboratory at least, to oviposit in those of the third and later instars. How long after oviposition the parasitic larva reaches full development and is ready to leave the host apparently depends only to a small extent on the instar of oviposition, but the time is likely to vary widely according to prevailing temperatures. In warm weather (83° F.) it may be as short as seven days, but in cool weather (69–70° F.) it may be as much as 14 days, and at lower temperatures it would probably be much longer. Whatever the duration of this interval, the parasitic larva always leaves the caterpillar during the fifth instar of the caterpillar's life and the caterpillar does not die immediately. In spite of the perforation in its body-wall, through which the parasite makes its exit, it may live several days. The parasitic larva, meanwhile, proceeds to spin a cocoon and to transform within it into a pupa and later into the fully developed wasp. Still, according to Vickery, the first of these transformations takes place soon after completion of the cocoon and the second shortly before emergence of the wasp, so that for practical purposes the time from the spinning of the cocoon to the emergence of the wasp can be considered equivalent to the duration of the pupal stage. This was observed by Vickery to vary between five days at a mean temperature of 83° F. to 17 or 19 days at the unspecified but presumably much colder temperatures of January.

The potential rate of reproduction of the species is indicated by Vickery in his statement that *Meteorus* can probably complete 18 generations during the year, and in his observation of one female which in the course of nine days successfully parasitized 83 caterpillars.

While the adults of *Meteorus* are small and inconspicuous wasps, their cocoons are curious and very characteristic objects which despite their small size are certain to attract attention. Of unusually tough texture, they are about four mm. long, spindle shaped, tapering from the middle to both ends, and a polished brown in color, their special character being due to the manner of their attachment to the host plant. Instead of resting directly on a leaf or stem they hang from one end on a thin, tough thread two or three inches long and swing wildly with the lightest breeze. Undoubtedly such an attachment is of some use as a protection against predatorial enemies of the species; but in a stiff Texas "norther" one is always led to wonder how many of the delicate *Meteorus* larvae might have gladly exchanged a measure of safety for a little more comfort. Particularly in view of the fact that at least one of the hyper-parasites of the species, a small, thick-legged wasp of the genus *Spilochalcis,* is often found clinging stoutly to the cocoons of the host and ovipositing therein in obviously calm disregard of the wild gyrations of its perch.

As was the case with our other species, it was not necessary to breed this parasite in the laboratory. Cocoons were collected in the field and sent to Hawaii as such or kept in Brownsville until the adults had emerged. The shipping cages used were of a type employed often before in similar work,* and the only innovation in our manner of using them consisted in the frequent inclusion of cocoons with the adults. For this purpose cocoons were crowded into a small pill box securely nailed to the inside of the cage and perforated with a number of small holes through which

* Petersen, Alvah, 1934. A manual of entomological equipment and methods. Edward Bros., Ann Arbor, Mich.

wasps emerging in transit could crawl out to join the other wasps in the cage, wherein food and moisture were provided by means of raisins and a small vial with a wick. In our first shipment some mortality of the adults occurred because the cocoons in the pill boxes were too crowded and emerging wasps were not able to push their way through them; but in later shipments the cocoons were divided into two pill boxes and the factor of overcrowding was eliminated.

From June to November of 1942, seven shipments of *Meteorus* were made, totalling some 3,200. Many of the adults were dead or too weak to be of use upon arrival in Honolulu. Nevertheless, some two-thirds of all the material shipped reached Honolulu in good shape and most of it was liberated directly in the field. Counting these liberations and some progeny reared in the Honolulu laboratory about 3,900 wasps were distributed in various fields of Oahu, Maui, Kauai, and Hawaii between June 1942 and June 1943.

Rogas laphygma Viereck

This is another solitary endoparasite of the family Braconidae. Vickery and the writer reared it exclusively from *Laphygma frugiperda* in Texas, but in our Honolulu laboratory it also parasitized *Laphygma exempta* without hesitation. It oviposits in caterpillars of the first instar and attains full larval development in those of the fourth. Then, instead of crawling away from the remains of its victim as other parasites do, it spins a thin cocoon within the empty skin of the host and proceeds to pupate therein. The skin containing the parasite shrinks somewhat in size, acquires a dry, paper-like consistency and becomes entirely brown in color, and can be easily mistaken for a real cocoon of some other species. It is securely glued along its ventral surface to whatever object the caterpillar happens to die upon. On corn plants it is usually found on the leaves.

Vickery ranked *Rogas* eighth in importance among the parasites of *Laphygma frugiperda* and stated that it was found infesting only from one-half to two per cent of all the small caterpillars collected over a period of five years. To the present writer it seems that *Rogas* must attain at times a much greater incidence than this. The nature of our work impeded the keeping of quantitative records but, even without them, it was obvious that the cocoons of *Rogas* were present at times in corn plantings where no other parasites were to be found, or where they were very scarce. In one such field of some two acres it proved possible on one occasion to collect 200 cocoons in three days.

These cocoons plus 17 more constituted the only substantial shipment of *Rogas* that was made to Hawaii and, unfortunately, it was not quite successful, yielding only 47 vigorous adults. With this relatively small number of wasps to begin with and in the face of heavy mortality among their progeny no determined effort was made to establish the species. Only two small liberations were made—ten adults at Olaa Sugar Company on June 24, 1942, and 45 adults at Pepeekeo Sugar Company on August 11 of the same year—on the chance that they might prove unexpectedly successful.

Apanteles marginiventris (Cresson)

This is another small and inconspicuous braconid, more likely to be noticed in the field as a cocoon than in the adult stage. Its life history has not been thoroughly studied, but Viereck reared it in Brownsville from one or more species of *Prodenia*,

one species of *Autographa, Plathypena scabra* Fab., *Cirphis unipuncta* (Haw.), *Heliothis armigera* (Hubner), *Laphygma exigua* Hubner, and *Laphygma frugiperda* (S. and A.), and he observed that in the laboratory the wasps oviposit in the first instar of *Laphygma frugiperda* soon after the caterpillars hatch from the eggs and before they disperse from the immediate vicinity of their hatching. Oviposition takes place through a single flash-like stab of the ovipositor and it does not seem to discommode the victims in any way. Although they invariably fail to attain the full size of unparasitized caterpillars they continue to feed and to behave normally until their fourth instar. At this stage the larva of *Apanteles* has reached full growth and gnaws its way out of the caterpillar through a hole in the body wall which is often a remarkably large and angry wound but does not result in the immediate death of the caterpillar. The caterpillar crawls away to live several hours longer, and meanwhile the *Apanteles* larva proceeds to spin the cocoon in which it is to transform into a wasp.

The cocoon of *Apanteles,* as shown in the accompanying illustrations, is creamy white, sometimes tending to yellow, and is about three mm. in length by about one mm. in thickness in the middle. Its shape is that of a cylinder with both ends bluntly rounded, and on close inspection its walls are seen to be smooth and glossy only within, being downy and irregular outside because the outer layers of thread are not tightly woven. On corn and grasses the orientation of the cocoon is almost invariably parallel to the long axis of the leaf and, at least on grasses, the place of attachment is usually the median groove of the leaf. The attachment is secure and difficult to break without injuring the cocoon and is attained by means of threads whose

Fig. 2. Adult female wasp and cocoon of *Apanteles marginiventris* (Cresson); the latter showing the trap door-like cap over the opening through which the adult wasp has emerged.

ends are firmly glued to the substratum. Empty cocoons are sometimes not immediately distinguished from others because of the delicate manner in which the wasps make their exit from them. Instead of indiscriminately gnawing a ragged hole anywhere on the cocoon as some other parasites do, *Apanteles* makes a smooth circular cut near one end and issues by lifting the end of the cocoon like a conical trap door which after emergence of the wasp is likely to fall back to its original position and to hide the parasite's escape.

In Brownsville the present writer found that the cocoons of *Apanteles* are much more likely to occur on the exposed leaf sheaths of the host plant than within the protection of the spindle or near the stalk of the plant or near the ground, where caterpillars are as likely to be collected during dense infestations as anywhere else. Why this happens is not known, but in explanation two alternative possibilities may be postulated which may some day provide the basis for an interesting study. One of these is that some environmental factor or factors, possibly light, warmth, host-movement, or host-position, determines the precise time at which the full-grown larva of *Apanteles* leaves the host. The other, that the emergence of the parasite is not restricted within sharp limits of time and that some factor exists which causes the caterpillar to remain on the exposed leaves of the host-plant until the parasite has emerged. The question, of course, seems presently only of academic interest; but, as in the case of all such questions, it is not possible to foresee when it might become of economic significance as well.

The duration of the larval and pupal stages combined, that is, the time between oviposition and emergence of the adult *Apanteles* from its cocoon, was found by Vickery to vary considerably from one season of the year to another. During the warm summers of Brownsville it was only about ten days but during the cold winter months it lengthened to as much as 27 days. With us in Hawaii the average must lie closer to Brownsville's minimum than to its maximum, but it remains yet to be accurately determined, as do other fine points of the parasite's life history.

The introduction of *Apanteles* into Hawaii took place entirely during the last half of 1942. Employing the same methods and equipment with this species as with *Meteorus laphygmae*, three shipments of cocoons were made, the first on August 12, the second on November 12, and the third on November 16, and from this material a total of 664 vigorous adults was obtained in Honolulu. Some of these were mated in the laboratory and released at once, and with the rest a program of laboratory breeding was undertaken which between November 1942 and June 11, 1943, the date of the last liberation, produced 4,277 adults distributed to the various islands as follows: to Hawaii, fifteen consignments totalling 2,126 adults; to Maui, eight consignments totalling 1,410 adults; to Oahu, two consignments totalling 230 adults; to Kauai, two consignments totalling 511 adults.

Vickery wrote that less than two per cent of his collections of five years in the Gulf District of Texas were parasitized by *Apanteles marginiventris;* but, as Vickery himself believed, this figure is probably an under valuation of the importance of the species. Although in the experience of the present writer *Apanteles* was not as easy to find on corn as *Chelonus* or *Meteorus* or even *Rogas laphygmae*, it was often common and at times noticeably abundant on grasses, appearing on more than one occasion as the main, if not exclusive factor in the elimination of small, dense populations of *Laphygma frugiperda.*

That *Apanteles* will also become an important factor in the control of armyworms and cutworms in Hawaii seems certain. The adaptability of the species to our conditions is shown by its quick establishment, and its value in our scheme of biological control is assured by its habits. Parasitizing exclusively the early instars of its various hosts, it will provide just the link that has been missing hitherto in our series of armyworm and cutworm parasites. With its addition to our fauna we now have one or more parasites working on each stage in the development of the hosts, from the egg stage to the mature larvae.

While so far most recoveries have been of the cocoon stage in grasses and weeds, indicating that *Laphygma exempta* and *L. exigua* will probably be the usual host of *Apanteles* in the Territory, on at least one occasion the parasite was reared from a field-collected caterpillar of *Heliothis armigera*. This is gratifying to record, for, since both *Apanteles marginiventris* and *Meteorus laphygmae* are known to parasitize *Heliothis* in the mainland United States, the establishment of both parasites in our Territory may well result in considerable reduction of the damage which *Heliothis* does to our increasingly important corn crop.

It is an interesting reflection upon the high biotic potential of the species, as well as upon the unpredictability of biological control in general, that *Apanteles* was first recovered, during February of 1943, on the grounds of the Experiment Station at Makiki, where the population of caterpillars had been judged too thin to warrant a formal liberation of any parasites and where *Apanteles* must have obtained a toe hold through the unsuspected efficiency of some few specimens which had been discarded as too old and spent for further laboratory breeding. The second recovery was made shortly after the first in the Pathology Plot on Alexander Street, where no liberations whatever had been made and where *Apanteles* can have arrived only by overcoming the hazards interposed by several blocks of densely populated urban property. Since then, recoveries have been made from other localities on Oahu (Waialua and Oahu Plantations) and from the islands of Kauai, Hawaii, and Molokai. On Kauai the first cocoon was found by C. E. Pemberton at Wailua Orchard on September 23, 1943. On Hawaii many cocoons and adults were found in April 1944 by Mr. Nagasako, Hawaiian Agricultural Company, Pahala, in the same fields and at the same time that *Meteorus* was first seen. The most remarkable record of all, however, is that of the recovery of *Apanteles* on the island of Molokai. It was first found there by Mr. Pemberton on April 21, 1944, and, since no liberations of the parasite were ever made on that island, it is presumed to have found its way there as an accidental stowaway on a ship or plane or as flotsam on air currents.

Soil and Plant Material Analyses by Rapid Chemical Methods—IV

The Clements' Method of Crop Control Adapted to RCM*

(Revised to RCM Procedure in a Laboratory Comparison Study by the Chemistry Department, Experiment Station, H.S.P.A., and Adjusted to Embrace Suggestions Based Upon a Critical Review by the Originator of the Method and His Staff.)

A summary of the Clements' method of crop control appeared in the Record *in the fourth quarter issue 1943. The present contribution consists of an adaptation of the analytical control determinations from standard laboratory practice to conventional RCM procedures. The revision and recasting of the analytical methods to RCM were made upon requests of plantation staffs interested in the study, and with the permission of Dr. H. F. Clements. A distinct contribution by the Chemistry staff of this Experiment Station embraces the tables appearing in the text of the RCM procedures and by which the analyst is relieved of the responsibility of making chemical calculations.*

The principles underlying this method of crop control were discussed and explained in an article by Dr. H. F. Clements.† Dr. Clements has in preparation additional subject matter and data which he will undoubtedly present in future published articles. Several plantations in the Territory are employing the method as outlined by the author and are making the necessary laboratory determinations on a scale comparable to that which would be carried out in any first-class, well-established chemical laboratory in the hands of university-trained chemists.

A number of plantation managers and their agriculturists have noted that the laboratory procedures used in the control method are somewhat technical and difficult to handle, and consequently are beyond the reach of adoption by the plantation RCM laboratory staff. Therefore, upon repeated requests from interested managers and agriculturists, and with the permission and cooperation of the author, the staff‡ of the Chemistry department of this Experiment Station undertook the

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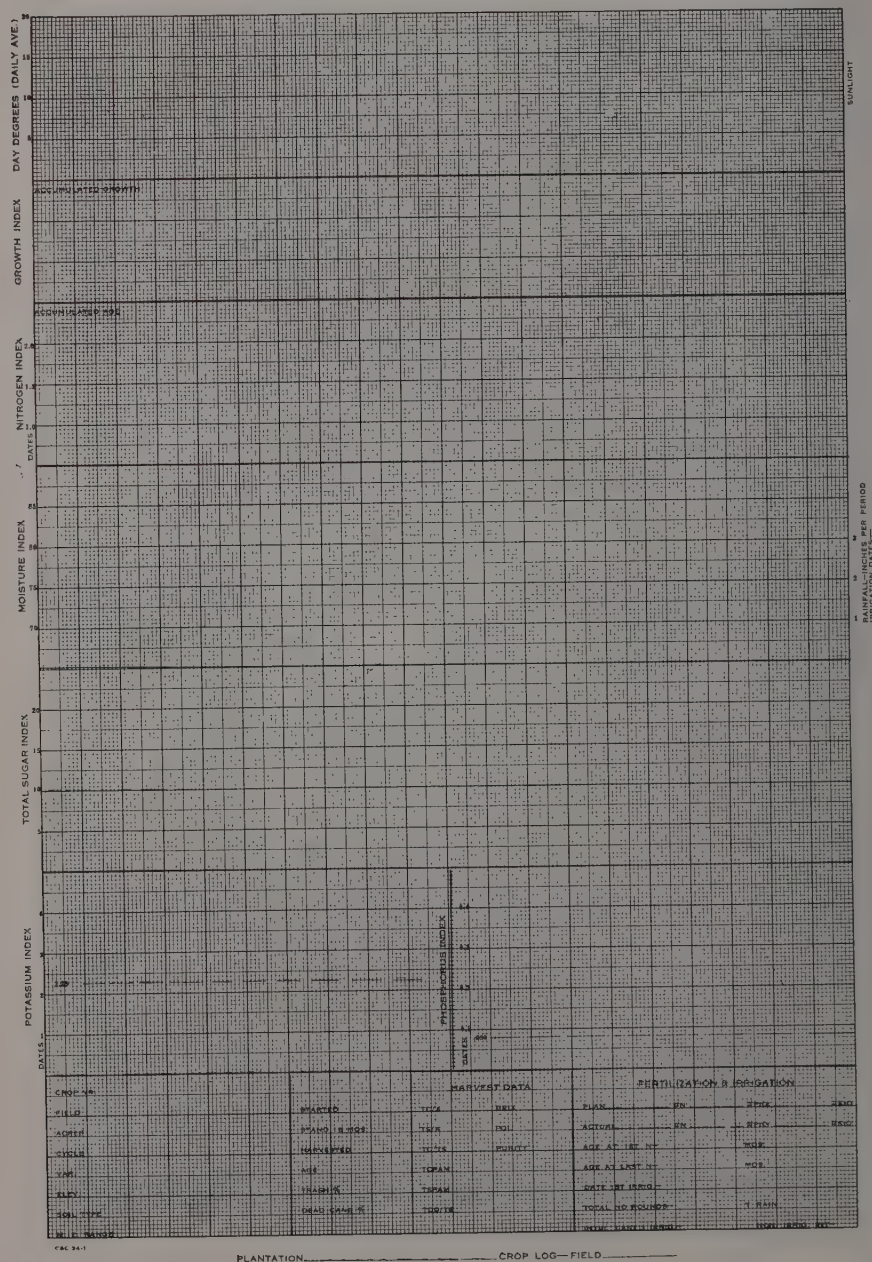
* The term "RCM" implies rapid chemical methods of soil and plant analyses. This abbreviation has been in use for about 15 years to designate a system of analyses developed at this Experiment Station and used by plantations and Experiment Stations throughout the Territory, and in a number of agricultural laboratories in South America, Europe, Africa, and Asia.

† The Primary Index, Its Meaning and Application to Crop Management With Special Reference to Sugar Cane. The Hawaiian Planters' Record, 47: 257–297, 1943.

‡ Several members of the Chemistry department, Experiment Station, H.S.P.A., contributed to the revision and recasting of the Clements' crop control analytical procedures. Those participating were M. Doi, Geo. K. Uyehara, F. Ray Van Brocklin, Richard Boyen, P. L. Gow and Francis E. Hance.

modifications and recasting of the procedures in simplified and chronological order on the basis of the laboratory technic which is common to RCM analyses. It was necessary to deviate somewhat from the original technic of analysis and to employ

Fig. 1. The Clements' crop-log form.



standardized reagents and equipment prepared for the RCM analyst in a chemistry laboratory. However, the principles of analytical procedure as described by Dr. Clements have not been materially altered. By adhering to the system adopted in previously developed RCM* procedures, the analyst using this recast of Clements' crop control is relieved of the necessity of making chemical calculations which might give him difficulty or result in erroneous findings. Instead, in all cases, his final analytical data are referred to convenient tables (attached hereto) where his end result may be found tabulated for him and from which the index he seeks may be noted and transferred to the crop-log sheet. This act terminates the duties of the RCM analyst. From this point forward the agriculturist takes over, for it is at this stage of the study that the "control" becomes operative.

The Clements' method of crop control is unique in that it employs periodic determinations made by the standard Experiment Station, H.S.P.A., leaf-punch nitrogen analysis of cane blade specimens as a running index of this nutrient. In addition to this, it includes a study made progressively with the growth of the crop upon the moisture, sugars, potassium and phosphorus relationships as they may exist from period to period and as they may vary in the leaf-sheath portion of the sugar cane plant.

The control is regulated by information recorded on a printed crop-log form prepared by Dr. Clements (Fig. 1). It constitutes essentially a running record of the growing crop. It carries determinations of nutrient values made from time to time on the plant, showing deficiencies or excesses of the principal fertilizer constituents. These data, together with other recorded observations, constitute the basis on which a diagnosis is made of the condition of the crop. Nutrient constituents may be applied to the current crop in an endeavor to correct deficiencies which the systematic log ostensibly has brought to light. The log records harvesting, fertilization and irrigation data, and nutrient indices, the latter falling within certain limits of concentration and which, by varying from predetermined values of sufficiency, supply data to the agriculturist upon which he may take action. The log sets forth, progressively under appropriate date lines, the following indices: potassium, phosphorus, total sugars, moisture and nitrogen. The log also embraces recordings of growth as an index and sets forth the daily average day-degrees of temperatures. Rainfall is noted on the log, together with irrigation data. Other field data are included which bear specifically upon the crop.

The RCM version of the control analyses deals only with laboratory procedures which bring the method within the reach of any RCM laboratory now operating. Apparatus, reagents, accessories and equipment (with few exceptions) are prepared and standardized in the RCM division of the Chemistry department and are being made available to plantation RCM staffs who wish to include the Clements' method of crop control in their field studies.

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* Hance, Francis E., 1936. Soil and plant material analyses by rapid chemical methods. The Hawaiian Planters' Record, 40: 189–299. (Agric. and Chem. Series Bulletin No. 50.)

————, 1937. Soil and plant material analyses by rapid chemical methods—II. The Hawaiian Planters' Record, 41: 135–186. (Agric. and Chem. Series Bulletin No. 51.)

————, 1941. Soil and plant material analyses by rapid chemical methods—III. The Hawaiian Planters' Record, 45: 265–296. (Agric. and Chem. Series Bulletin No. 53.)

The original text of the author has been inserted at various points (under quotes) to clarify certain phases of the procedure. Several revisions have been made from the RCM recasting of the method as based upon constructive criticism and suggestions by the author of the method and his staff. We offer the regular RCM checking service which, as in the case of other RCM studies, is made available to the plantations without charge.

The Experiment Station recommends that, should the plantations decide to include the Clements' method of crop control in their research curriculum, the RCM operator who may be selected for the work be given a 10- to 20-day course of instruction in the Chemistry department of this Experiment Station prior to his undertaking the study on the plantation.

Factors Governing Selection of Cane Stalks for Sampling

In using Clements' method of crop control it is necessary to recognize certain comparatively simple facts, especially with reference to sampling.

First: The final crop of sugar cane is made up of those sticks which have survived the competition of the previous period of growth. Thus at about three months of age, a cane crop may average anywhere from six to as many as twelve young shoots per running foot of line. These include some strong and some weak shoots. Usually, by the time the crop is a year old, the weaker shoots are dead and dried up. These dead shoots either decay, or what remains of them is destroyed by the slash fire at harvest. Only the stronger shoots succeed in contributing to the harvest. It is, therefore, apparent that samples selected should represent the average of the strong tops, that is, those which are likely to be there at harvest.

Second: Suckers which develop after the crop is from 10 to 14 months old usually contribute a small part of the final crop. Where such is the case it is obvious that suckers should not be included in the samples. Actually the sucker growth differs considerably from the main crop, not only in age, but in succulence and hence cannot be mixed into the samples. However, where the late sucker growth is considerable, so that an estimate would place that portion of the crop at about 50 per cent of the total, it is clear that two crops are growing in the field and separate samples must be taken from the sucker crop. At best, we can only hope to bring the two crops to harvest with least damage to either one. It is therefore apparent that one does not sample a field according to mathematical chance. He *selects* his plants as representing the major stand of plants which will be there at harvest.

Third: The size of the area included in a single sample will be determined by the nature of the area. If the field is uniform in elevation, exposure, slope and moisture, it can be sampled as a single area, no matter how large it is. If, on the other hand, the area is small but extremely variable in slope and moisture, etc., it will be necessary to have two or more sampling areas. Thus a field with sharp gullies and ridges can best be handled by sampling the ridges as one area and the gullies as another. Or, if a field is a narrow strip on a steep slope, so that considerable variation in elevation obtains, it may be necessary to divide the field into two or more areas. Again, one must consider the percentage factor in laying out sampling areas. If a field is largely one kind of area, with minor parts of the field at variance, he may decide to ignore the spots or smaller areas. Or he may sample these separately.

It is clear, therefore, that the size of the field area sampled has to be decided for each particular field with special attention given to variations in slope, elevation, exposure, drainage and moisture. When this method is to be applied to a new field, it is best to break the field into several sampling areas. After the samples are analyzed, the smaller areas can be combined into larger areas as determined by the uniformity of the analyses.

Fourth: A little experience on the part of the sampler is needed. At first he should be required to select several samples from small areas. In selecting a sample, the plants making up the important stand are taken. These should be selected well away from borders and main irrigation ditches and should be taken from several representative spots in the field.

Fifth: Since in this method we are interested in obtaining a picture of the general physiological status of the crop, we need to avoid as much as possible the influences of the day on

which the samples are taken. It is therefore necessary to collect the samples early in the morning—preferably just after sunup and to limit sample gathering to the first two or three hours of the day.

Sixth: Samples are collected at intervals of five weeks, beginning as soon as the small plants have the necessary leaves and sheaths.

Preparation and Storage of Sample

The sample is made up of tops of five representative plants selected as described above. Having selected a particular plant, find the spindle leaf—the one sticking out of the top of the plant—and call it No. 1. Count the leaves downward in order through No. 6. Cut the stalk somewhere below the attachment of this leaf without removing the older leaves. (If these leaves are left on, the same stalk remaining in the field will develop lalas and will not be lost.) One sample consists of five such tops removed from various parts of the fields. If many samples are to be gathered in one morning, it is best to roll each five tops into a bundle and to label properly. The label may be written with a No. 2 (soft) pencil directly on the exposed sheath of each top. KEEP THE SAMPLE CLEAN AT ALL TIMES.

The sample or samples are taken to the laboratory and leaves Nos. 3, 4, 5 and 6 are carefully removed from the stalk. This is best accomplished by using a strong sharp knife. The stalk is cut across exactly at the point of contact of the sheath to the stem. After the cut, the sheath is rolled off. Then the next cut is made across the base of the next sheath, etc. It is important that the cut be clean so that no cane tissue is carried by the sheath. With practice this operation takes very little time. Since each top will give four leaves, each sample will give twenty such leaves. The remaining material is discarded. Each of the twenty leaves is then separated at the brown mark into sheath and blade.

After determining the moisture and green weight (procedure outlined below) the dried material is ground to a near powder and may be stored until analysis. If several weeks pass before analysis, the sample should be redried before weighing.

Determination of Moisture and Green Weight

(Adapted from Dr. Clements' original text)

Equipment:

1 balance, capacity 1,500 grams
1 set balance weights, 1 mg. to 1,000 grams
1 butcher knife or cutter (paper-cutter type)
1 drier*
1 grinding mill

Procedure:

1. Weigh each bundle (20 sheaths each) on an accurate balance. Record weight. This is GREEN WEIGHT of the sample.

2. After weighing (using a strong, sharp knife of the paper-cutter type), cut sheaths into half-inch lengths.

3. Place chopped sample on a screen tray in the drier (equipped with a strong blast and enough heat to maintain approximately 90° C.) for about three hours.

4. Test completion of drying by reweighing the sample and returning it to drier for another hour.

Note: As the operator gains experience, he can take pieces of the chopped sheaths and test their dryness by the way they snap when bent.

5. Weigh dried sample on accurate balance and record weight. This is DRY WEIGHT OF SAMPLE.

6. Subtract DRY WEIGHT from GREEN WEIGHT. The result is MOISTURE CONTENT.

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* Blueprints of an efficient drier are now available from the Engineering Committee, Experiment Station, H.S.P.A.

7. The MOISTURE CONTENT, when multiplied by 100 and divided by GREEN WEIGHT of sample gives PER CENT MOISTURE or MOISTURE INDEX.

The Nitrogen Index by RCM

The twenty leaf blades referred to above under "Preparation and Storage of Sample" are the tissues used in this analysis. Three leaf punches are taken from each leaf in a region located about half way along the blade and one-half the distance between the midrib and the outer edge of the leaf. Details of the method to be used in determining the nitrogen index have previously been published.* Follow the analytical procedure in the leaf-punch method, but employ the Clements' technic for collecting the sample.

Primary Index (Total Sugars) by RCM

Reagents:†

5 gallons distilled water	1 gallon reagent 47, S	1 gallon reagent 50, S
½ pint reagent 45, S	1 gallon reagent 48, S	
1 gallon reagent 46, S	½ pint reagent 49, S	

Equipment:

1 student-type analytical balance, sensitive to 0.1 mg.
1 aluminum balance scoop, 10-ml., with counterpoise
10 Erlenmeyer Pyrex flasks, narrow mouth, 500 ml.
1 hot-water bath
10 rubber stoppers No. 6 fitted with 15″-length of 13-mm. glass tubing, for 500-ml. Erlenmeyer flasks
1 wooden clamp for removing flasks from source of heat
10 glass funnels, 90-mm. diameter
1 pkg. Munktell No. 3, 15-cm. filter paper
10 volumetric Pyrex glass flasks, 500 ml.
1 five-gallon bottle fitted with stopper and siphon for distilled water
10 feet ¼ x 1/16″ rubber tubing with glass nipple and pinchcock for siphon
10 Pyrex beakers, 600 ml.
10 volumetric Pyrex flasks, 250 ml.
1 graduated cylinder, 250 ml., for transferring filtrate to volumetric flask
1 electric hot plate, 3-heat
1 Mohr pipette, 10 ml., for reagent 50, S
1 dropping bottle, pipette stopper, 60 ml., for reagent 45, S
1 burette, 50 ml., for reagent 46, S
1 burette, 50 ml., for reagent 47, S
10 Erlenmeyer Pyrex flasks, narrow mouth, 300 ml.
1 Mohr pipette, 5 ml., for reagent 48, S
1 burette, 50 ml., for inverted extract

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* Hance, Francis E., 1941. Soil and plant material analyses by rapid chemical methods—III. The Hawaiian Planters' Record, 45: 265–296. (Agric. and Chem. Series Bulletin No. 53.)

† Complete details regarding the preparation of reagents are included elsewhere in this article.

2 iron support stands, 6 x 9″ base, with rods } for 50-ml. burettes
2 Lincoln burette clamps }
1 dropping bottle, pipette stopper, 60 ml., for reagent 49, S
1 thermometer, 0–100° C.

Procedure:

1. Weigh out exactly five grams of the ground and dried sheath material and place in a 500-ml. Erlenmeyer flask.

2. Add 300 ml. of distilled water and place flask on electric hot plate* for three hours at near boiling. Stopper flask and fit with a 15″ length of fairly large glass tubing in order to materially reduce losses from evaporation.

3. Using a wooden clamp, remove flask from hot plate and filter through Munktell No. 3, 15-cm. filter paper (using 90-mm. funnel) into a 500-ml. volumetric flask.

4. Wash residue remaining on filter five times with 20 to 30 ml. of distilled water each time. Direct stream of distilled water entirely around the upper edges of the filter paper about ¼-inch from top. Allow distilled water to drain thoroughly after each washing.

5. Discard residue.

6. Make filtrate up to volume (500 ml.) with distilled water and mix thoroughly by pouring all of the filtrate into a clean, 600-ml. beaker.

Note: This filtrate contains sucrose, reducing sugars and potash.

7. Using a 250-ml. graduated cylinder, transfer accurately 200 ml. of the filtrate to a 250-ml. volumetric flask and heat on hot plate to 65–70° C.

8. Before removing flask from hot plate, from a 10-ml. Mohr pipette immediately add 10 ml. of reagent 50, S to contents of flask.

9. Remove flask from heat with wooden clamp; let it stand for one hour.

10. Cool to room temperature and then add five drops of reagent 45, S from dropping bottle.

11. Carefully neutralize with reagent 46, S from a 50-ml. burette to faint pink color.

12. Make up to mark (250 ml.) with distilled water and mix thoroughly.

Note: This represents the INVERTED EXTRACT.

13. From an accurate 50-ml. burette measure exactly 5 ml. of reagent 47, S into a 300-ml. Erlenmeyer flask.

14. Using a 5-ml. Mohr pipette, add 5 ml. of reagent 48, S.

15. From another accurate 50-ml. burette, add 25 to 30 ml. of inverted extract (from step No. 12).

Note: Add more of the inverted extract if the percentage of sugars is known to be low.

16. Place flask on the type "H" electric heater. (Reverse heater refractory so that its bottom or flat surface faces upward.) Add three to four perforated glass beads to contents of flask. Heat contents to boiling and continue to boil for exactly two minutes.

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* In regular, established laboratories the following procedure may be followed in Step No. 2: Add 300 ml. of distilled water and place flask in a hot-water bath (near boiling). Heat for three hours. (*Note:* Blue prints for a suitable water bath are available at the office of the Engineering Committee, Expt. Sta., H.S.P.A.)

Note: If the solution in the flask is still quite blue after it starts to boil, add *carefully* more of the inverted extract from the burette until the bluish tint disappears. (Burette reading will be needed later.)

17. After boiling for two minutes, and while flask remains on heater, add from dropping bottle five drops of reagent 49, S. Arrange burette containing inverted extract so that titration with inverted extract may be made without removing flask from heater. Add more inverted extract, a little at a time, until blue color occasioned by addition of reagent 49, S completely disappears. (Do not remove flask from heater until titration has been completed. Titration should be completed within one minute after boiling.)

18. Remove flask from heater and record exact burette reading.

Note: If no color develops in solution in Erlenmeyer flask upon addition of reagent 49, S, too much inverted extract has been added. If more than 89.0 ml. of inverted extract were required to decolorize 5 ml. of reagent 47, S make another extraction using ten grams of ground sheath material and divide indicated percentage by two.

19. Read percentage of invert sugar in the dried sample directly from table.

Example:

5 grams ground sheath material extracted.

48 ml. = titration with inverted extract.

From table: 48 ml. = 13.62 per cent total sugars in original dry material, expressed as invert sugar.

TABLE OF PER CENT INVERT SUGAR IN FIVE GRAMS OF ORIGINAL DRY SAMPLE

ml. inverted extract used	Per cent invert sugar	ml. inverted extract used	Per cent invert sugar	ml. inverted extract used	Per cent invert sugar
20	31.87	43	15.12	66	10.25
21	30.37	44	14.87	67	10.12
22	29.00	45	14.50	68	10.00
23	27.75	46	14.25	69	9.90
24	26.62	47	13.87	70	9.80
25	25.62	48	13.62	71	9.70
26	24.62	49	13.37	72	9.60
27	23.75	50	13.12	73	9.50
28	23.00	51	12.87	74	9.40
29	22.25	52	12.62	75	9.30
30	21.37	53	12.37	76	9.20
31	20.75	54	12.12	77	9.10
32	20.12	55	11.87	78	9.00
33	19.62	56	11.75	79	8.90
34	19.00	57	11.62	80	8.80
35	18.50	58	11.37	81	8.70
36	18.00	59	11.25	82	8.60
37	17.50	60	11.12	83	8.50
38	17.12	61	10.87	84	8.40
39	16.62	62	10.75	85	8.30
40	16.25	63	10.62	86	8.20
41	15.87	64	10.50	87	8.10
42	15.50	65	10.37	88	8.00
				89	7.90

Note: If the titration goes beyond the limit of this table, it will be necessary to repeat the extraction using ten grams of the ground sheath material. When a ten-gram sample is used, indicated percentage (from table) should be divided by two.

The Potassium Index by RCM*

Reagents:

1 pint reagent 41, K
1 quart reagent 42, K
1 quart reagent 43, K
1 pint reagent 44, K

Equipment:

1 volumetric pipette, Exax, 20 ml., for transferring aliquots of sugar extract
12 Pyrex beakers, 250 ml.
12 watch glasses, 3½″-diameter, to cover 250-ml. beakers
Note: An electric refrigerator should be available within easy access of laboratory for cooling and storing speciments, and ice-cold distilled water and distilled water ice cubes required in the procedure.
1 Mohr pipette, Exax, 5 ml., for reagent 41, K
12 glass stirring rods, 6″-length
12 Gooch crucibles, 20 ml.
1 asbestos stamper
1 crucible holder for Gooch crucibles
10 grams asbestos specially prepared for this determination
1 filter pump, brass, ⅜″ pipe thread with ⅜″ coupling.
1 filtering flask, 1000 ml., with side tube and 3-ft. length of rubber tubing
1 screw-cap chemical bottle (1½ to 2-liter capacity) provided with opening in cover for siphon
1 glass siphon (5 mm. glass tubing, with 3-ft. length of rubber tubing fitted with glass nipple and stopcock)
2 burettes, Exax, 50 ml., for reagents 43, K and 44, K
2 support stands, iron, 6 x 9″ with rods } for 50-ml. burettes
2 Lincoln burette clamps }
1 special pipette, 5 ml., for reagent 42, K
1 electric heater (any type available) or Bunsen burner

Procedure:

Note: This analysis must be conducted in duplicate and in a laboratory that is free from ammonia fumes.

1. Mix the 500 ml. of sugar extract thoroughly and pipette 20 ml. into a clean 250-ml. beaker.

2. Cover the beaker with a watch glass and cool to 10° C. (or lower) in refrigerator.

3. Add 5 ml. of reagent 41, K by means of a 5-ml. Mohr pipette, stirring the solution vigorously with a glass rod. Place the beaker in the refrigerator overnight; allow glass rod to remain in beaker and cover the beaker with a watch glass.

4. Set up a Gooch filter, as follows:

(*a*) Prepare an asbestos suspension by mixing five grams of specially prepared asbestos and one liter of distilled water. Keep the mixture in a covered jar. Before using, shake the asbestos mixture to get a homogeneous suspension, and pour immediately a convenient quantity into a beaker.

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* An adaptation of: Volk, N. J., and Truog, E., 1934. A rapid chemical method for determining the readily available potash of soils. Jour. Am. Soc. Agr., 26: 537–546.

(*b*) Fit the crucible holder to the filtering flask. Place the crucible in the receptacle of the crucible holder. Pour asbestos (stir well before each pouring with a glass rod) into the crucible about ¾ full, and let the water drain through for a few seconds without suction.

(*c*) Then apply suction. Immediately, after the excess water is drawn out, compact the asbestos by stamping several times with the stamper.

(*d*) Again pour additional asbestos suspension into the crucible to about ¼ capacity and compact the pad as before. Wash the asbestos felt which will be formed with distilled water several times. Examine the asbestos felt, holding the crucible up to the light. If no light comes through the bottom (pad too thick) or if the openings are too plainly seen (pad too thin), the mat must be discarded and a new one prepared.

Note: Do *not* dispose of asbestos. It may be used over and over again after purification. Purification may be accomplished by washing, through suction, several times with distilled water. Return to original jar. Add sufficient distilled water to have approximately the original asbestos concentration (five grams per liter).

5. Arrange for a supply of ice-cold distilled water (10° C. or lower). Prepare a tray of ice cubes using distilled water. Place cold water in chemical jar. (This may be accomplished by leaving the distilled water in the jar in the refrigerator overnight and then adding a few distilled-water ice cubes to it just before using.) Insert siphon through the hole in the cover.

6. Transfer contents of cold beaker (which has stood overnight in refrigerator) to the prepared crucible. The precipitate will collect on the mat in the Gooch crucible. Wash beaker and stirring rod with a few ml. of ice-cold distilled water. Use only enough to rinse the sides of the beaker with a thin film. Transfer washings to the Gooch crucible. Repeat the washing of beaker and rod with transfer of washings to Gooch crucible *five successive times*. It is very important to hold the total volume of wash water used to the smallest possible quantity. Now wash the Gooch crucible *five additional times* using only a few ml. of ice-cold distilled water for the entire operation. Wash outside of Gooch crucible with a little of the ice-cold distilled water after removing from the holder.

Note: In transferring the solution from the beaker to the crucible, use a glass stirring rod held securely against the lip of the beaker. The stirring rod, down which the liquid runs, should never be drawn up in such a way as to allow the solution to collect on the under side of the lip of the beaker. In washing, the stream of distilled water should always be directed around the upper edge of the crucible, and wash water should always be allowed to drain to the last drop after each addition.

7. Loosen the asbestos pad carefully with the stirring rod and place Gooch crucible and rod into original beaker.

8. Add enough hot distilled water (at about boiling point) to cover the Gooch crucible.

9. Carefully noting the volume used add, first, a few ml. of reagent 43, K from burette and follow immediately with 5 ml. of reagent 42, K using the special 5-ml. pipette. Do not allow the purple color to fade out. Stir the mixture vigorously to break up the asbestos pad. Continue to add reagent 43, K until an excess of reagent remains.

10. Place the beaker with contents on an electric heater (or over a low flame)

and heat to boiling. (Stirring may be necessary to prevent bumping.) If the purple color begins to disappear, add more reagent 43, K immediately from the burette. (Remember that the burette reading will be noted later.)

11. Remove the beaker from the heater and add 2 ml. of reagent 44, K from its burette, while stirring. The purple color should disappear. If not, then continue with a few drops of reagent 44, K in excess of the fading point.

12. Add reagent 43, K (drop by drop while stirring) to the end point.

Note: The end point is obtained when one drop of reagent 43, K in excess imparts a distinct pink color to the solution which does not fade for one minute.

13. Read both burettes to the nearest 0.05 ml.

Note: In reading the burettes, read the *top* of the meniscus for reagent 43, K and the *bottom* of the meniscus for reagent 44, K. The eyes should be directly opposite the point read.

14. Subtract ml. of reagent 44, K from ml. of reagent 43, K to obtain a net ml. of reagent 43, K. (Make a blank determination on each lot of asbestos, and if the titration figure is appreciable, subtract it from the net ml. of reagent 43, K.)

15. Take the average ml. of reagent 43, K of the duplicate determinations and refer to the Table of Per Cent Potassium in Cane Sheath Material.

Note: If the difference in ml. of reagent 43, K used between duplicates exceeds 0.30 ml., discard the result and repeat the analysis.

.20 ml. = .03% .30 ml. = .05% .40 ml. = .07%

16. Refer to the Table of Factors for Potassium Index.

17. Per Cent K *X* Factor = K Index.

Example:

Ml. of reagent 43, K = 12.75 ml.

Referring to Table of Per Cent K, 12.75 ml. of reagent 43, K = 2.08%.

Per cent sugar (from analysis) = 15.55.

Referring to Table of Factors for Potassium Index, Factor = 1.18.

Then, Per Cent K *X* Factor = K Index, or $2.08 \times 1.18 = 2.45\%$.

TABLE OF PER CENT K IN CANE SHEATH MATERIAL

% K = .1630 X ml. of reagent 43, K on the basis of 5-gram sample (dry wt.)

A		B	
ml. of reagent 43, K	Per cent K	ml. of reagent 43, K	Per cent K
.05	.01	1.00	.16
.10	.02	2.00	.33
.15	.02	3.00	.49
.20	.03	4.00	.65
.25	.04	5.00	.82
.30	.05	6.00	.98
.35	.06	7.00	1.14
.40	.07	8.00	1.30
.45	.07	9.00	1.47
.50	.08	10.00	1.63
.55	.09	11.00	1.79
.60	.10	12.00	1.96
.65	.11	13.00	2.12
.70	.11	14.00	2.28
		15.00	2.44
		16.00	2.61
		17.00	2.77
		18.00	2.93
		19.00	3.10
		20.00	3.26
		21.00	3.42

TABLE OF PER CENT K IN CANE SHEATH MATERIAL (*Continued*)

% K = .1630 X ml. of reagent 43, K on the basis of 5-gram sample (dry wt.)

A		B	
ml. of reagent 43, K	Per cent K	ml. of reagent 43, K	Per cent K
.75	.12	22.00	3.59
		23.00	3.75
.80	.13	24.00	3.91
		25.00	4.08
.85	.14	26.00	4.24
		27.00	4.40
.90	.15	28.00	4.56
		29.00	4.73
.95	.15	30.00	4.89
1.00	.16	31.00	5.05

To obtain % K when the volume of reagent 43, K exceeds 1 ml., locate the value of % K corresponding to a fraction of 1 ml. from Column *A*, and add it to the proper value of % K in Column *B*.

Example:

ml. of reagent 43, K = 12.55.

12.00 ml. (Col. B) + .55 ml. (Col. A) = 1.96% K + .09% K = 2.05% K.

Note: When a 10-gram sample is used for sugar extraction, indicated percentage (from table) should be divided by two.

TABLE OF FACTORS FOR POTASSIUM INDEX

$$\text{Factor (F)} = \frac{100}{100 - \%\ \text{sugar}}$$

% sugar range	Factor	% sugar range	Factor	% sugar range	Factor
0.0–0.4	1.00	11.9–12.6	1.14	22.2–22.7	1.29
0.5–1.4	1.01	12.7–13.4	1.15	22.8–23.3	1.30
1.5–2.4	1.02	13.5–14.1	1.16	23.4–23.9	1.31
2.5–3.3	1.03	14.2–14.8	1.17	24.0–24.5	1.32
3.4–4.3	1.04	14.9–15.6	1.18	24.6–25.0	1.33
4.4–5.2	1.05	15.7–16.3	1.19	25.1–25.6	1.34
5.3–6.0	1.06	16.4–17.0	1.20	25.7–26.1	1.35
6.1–6.9	1.07	17.1–17.7	1.21	26.2–26.7	1.36
7.0–7.8	1.08	17.8–18.3	1.22	26.8–27.2	1.37
7.9–8.6	1.09	18.4–19.0	1.23	27.3–27.7	1.38
8.7–9.5	1.10	19.1–19.6	1.24	27.8–28.3	1.39
9.6–10.3	1.11	19.7–20.3	1.25	28.4–28.8	1.40
10.4–11.1	1.12	20.4–20.9	1.26	28.9–29.3	1.41
11.2–11.8	1.13	21.0–21.5	1.27	29.4–29.8	1.42
		21.6–22.1	1.28	29.9–30.3	1.43

The Phosphorus Index by RCM*

Reagents:

1 quart reagent 51, P
½ gallon reagent 52, P
¼ pint reagent 53, P
½ pint reagent 54, P
½ pint ammonium molybdate solution (9.6 *N*)
½ pint stannous chloride solution
1 pint standard phosphate solution (5 p.p.m. P.)

Equipment:

1 Bunsen burner
1 electric muffle
6 type "H" electric heaters
1 student-type analytical balance, sensitive to 0.1 mg.

* An adaptation of: Truog, Emil, and Meyer, A. H., 1929. Improvements in Denigès colorimetric method of phosphorus and arsenic. Ind. and Eng. Chem. (Analytical Ed.) 1: 136–139.

1 balance scoop, aluminum, 30 ml., with counterpoise
6 porcelain crucibles, 30 ml.
6 beakers, Pyrex, 600 ml.
6 volumetric Pyrex flasks, 500 ml.
12 Erlenmeyer Pyrex flasks, 125 ml., narrow mouth
1 graduated cylinder, Exax, 10 ml., for reagent 52, P
1 graduated cylinder, Exax, 50 ml., for distilled water
1 graduated cylinder, Exax, 100 ml., for preparation of standard solution
6 Nessler tubes, short form, 100 ml.
6 glass funnels, 65-mm. diameter
1 volumetric pipette, Exax, 5 ml., for transferring stock solution
1 Mohr pipette, Exax, 10 ml., for reagent 51, P and ammonium molybdate solution
1 volumetric pipette, Exax, 10 ml., for transferring aliquots of prepared sample
1 volumetric pipette, Exax, 5 ml., for transferring aliquots of prepared sample
1 volumetric pipette, Exax, 3 ml., for transferring aliquots of prepared sample
6 glass rods, 7″-length
A small supply of white typing paper
1 pair crucible tongs, nickel, 9″-length
1 dropping bottle, pipette stopper, 60 ml., for stannous chloride solution
1 dropping bottle, pipette stopper, 60 ml., for reagent 53, P
1 bottle, ¼-pint capacity, paraffin-coated, rubber stopper with dropper fitted, for reagent 54, P
6 triangles, wire, 2″
6 rubber policemen

Procedure:

1. Weigh out one gram of the ground and dried sheath specimen in a balance scoop; transfer to a porcelain crucible.

2. Add 2 ml. of reagent 51, P using a 10-ml. Mohr pipette.

3. Ash on type "H" electric heater in the following manner: Reverse heater refractory so that its bottom or flat surface faces upward. Place the crucible, supported by triangle, in hole of refractory. Turn on heater and ash for ½ hour.*

Note: Disconnect heater after each ashing operation; allow heater to cool before ashing additional samples.

4. Remove crucible from heater and allow it to cool. Moisten ash with a few ml. of distilled water to avoid spattering. Using a 10-ml. graduated cylinder, add 10 ml. reagent 52, P to the residue; let stand for at least one hour.

5. Transfer (through a 65-mm. funnel) the entire contents of the crucible into a 500-ml. volumetric flask. Scrub inside of crucible with rubber policeman and wash the inside of the crucible repeatedly with distilled water; make up to volume (500 ml.).

* For purposes of RCM, this procedure (Step No. 3) will be found more suitable and efficacious. However, in regular, established laboratories, the following method may be followed: Ignite with gas flame. When alcohol has been consumed, warm crucible cautiously and gently over gas flame (low heat) until ignition is complete. Ash overnight in electric muffle at red heat or lower (below 800° C.).

6. Pour into 600-ml. beaker and mix thoroughly, using a glass stirring rod. Allow solution to stand for a few moments to permit insoluble material to settle.

7. Pour slowly (decant) the clear supernatant solution back into the 500-ml. volumetric flask; discard material remaining in beaker.

8. Using a 5-ml. volumetric pipette, transfer a 5-ml. aliquot (take a 10-ml. aliquot if phosphorus concentration of sample is low; if phosphorus concentration is high, use a 3-ml. aliquot) into a 125-ml. Erlenmeyer flask and dilute to 50 ml. with distilled water, using a 50-ml. graduated cylinder.

9. Add one drop of reagent 53, P, and reagent 54, P (drop by drop) until color of the test solution becomes just faintly yellow.

10. Add two ml. of ammonium molybdate solution with a 10-ml. Mohr pipette and mix well (swirling motion).

11. Add three drops of stannous chloride solution from dropping bottle. Compare with standard solution, as follows:

Note: Standard solution should be prepared before completion of Step No. 11. See Step No. 12 for preparation of standard solution.

(*a*) Transfer the contents of the Erlenmeyer flask containing the unknown (test solution) into a 100-ml. Nessler tube. Standard solution remains in 100-ml. graduated cylinder.

(*b*) Hold the Nessler tube containing the test solution, together with an empty Nessler tube, in one hand over a white background. (Fold a sheet of white typing paper in half, lengthwise, and stand it up on both edges. Then hold Nessler tubes so that the tube bottoms are bisected by the crease in the paper.)

(*c*) Pour the standard solution from the graduated cylinder into the empty Nessler tube until the colors match when sighted from the top of the tubes. If an excess of standard solution is added, pour it back into the graduated cylinder and repeat the matching operation.

Note: If possible, use a constant source of white light in matching colors.

(*d*) Take reading of cylinder to ascertain amount of standard which you were required to use in operation (*c*).

Note: Standard solution in Nessler tube is poured back into graduated cylinder for subsequent comparisons during this analytical run only. Discard the standard solution when analyses are complete.

12. Prepare standard solution as follows: Using a 5-ml. volumetric pipette, transfer exactly 5 ml. of the stock solution (5 p.p.m. P) into a 100-ml. graduated cylinder. Dilute to 96 ml. with distilled water; add 4 ml. ammonium molybdate solution (using a 10-ml. Mohr pipette). Transfer to a 125-ml. Erlenmeyer flask and mix well (swirl contents of flask). Add six drops of stannous chloride solution from dropping bottle and mix well. A maximum blue color should develop almost immediately. The standard solution, containing 0.25 p.p.m. P, is now ready for use.

Note: Since the blue color developed in the standard solution will start to fade after standing about 10 minutes, a new standard should be made up accordingly.

13. Refer to table and determine percentage of Phosphorus in sample.

TABLE OF PERCENTAGES OF PHOSPHORUS IN DRIED CANE SHEATH MATERIAL

Ml. standard required	Ml. aliquots taken					
	3 ml.		5 ml.		10 ml.	
	p.p.m.	%	p.p.m.	%	p.p.m.	%
20	833	.08	500	.05	250	.03
21	875	.09	525	.05	263	.03
22	917	.09	550	.06	275	.03
23	958	.10	575	.06	288	.03
24	1000	.10	600	.06	300	.03
25	1042	.10	625	.06	313	.03
26	1083	.11	650	.07	325	.03
27	1125	.11	675	.07	338	.03
28	1167	.12	700	.07	350	.04
29	1208	.12	725	.07	363	.04
30	1250	.13	750	.08	375	.04
31	1292	.13	775	.08	388	.04
32	1333	.13	800	.08	400	.04
33	1375	.14	825	.08	413	.04
34	1417	.14	850	.09	425	.04
35	1458	.15	875	.09	438	.04
36	1500	.15	900	.09	450	.05
37	1542	.15	925	.09	463	.05
38	1583	.16	950	.10	475	.05
39	1625	.16	975	.10	488	.05
40	1667	.17	1000	.10	500	.05

14. Find the factor for phosphorus index. (Refer to Table of Factors for Potassium Index.)

15. Per cent Phosphorus X Factor = Phosphorus Index.

Example:

A 5-ml. aliquot requires 26 ml. of standard solution.

Referring to table above, percentage of P = .07%.

Per cent of sugar (by analysis) = 12.53%.

Referring now to Table of Factors for Potassium Index, Factor = 1.14.

Then, per cent P X Factor = Phosphorus Index, or .07% X 1.14 = .08%.

Important Precautions: Arsenic produces exactly the same color as phosphorus in colorimetric analyses of this character. Pyrex glassware contains a small amount of arsenic oxide, so that the use of *new* Pyrex vessels may cause serious contamination. All glassware should, therefore, be treated with warm sulfuric-acid-dichromate solution for at least 24 hours. After this treatment, wash glassware and then rinse thoroughly with distilled water.

Note: The RCM division of the Chemistry department will furnish glassware treated as noted above upon request. A small charge will be made to cover the cost of this service.

Results which appear to be questionable should be checked by redeterminations.

Preparation of Reagents

Reagent 41, K (Sodium Cobaltinitrite Solution):

Dissolve 150 gm. of sodium cobaltinitrite, CP powder ($Na_3CO(NO_2)_6$) in 500 ml. of distilled water. When in solution, filter through asbestos on a Gooch crucible and keep in the refrigerator in tightly closed, glass-stoppered amber bottle. (This reagent may keep for several months; occasional checking is required.)

Reagent 42, K (Dilute Sulfuric Acid Solution, 1 + 4; 7.2 Normal):

Add one volume of concentrated sulfuric acid to four volumes of distilled water.

Reagent 43, K (Standard 0.05 Normal Potassium Permanganate Solution):

Dissolve 3.5 gm. of potassium permanganate, CP crystals in about one liter of distilled water, digest at or near the boiling point for a few hours, cool and allow to stand two or three days. Filter the solution through asbestos and make up to two liters. Standardize against $Na_2C_2O_4$. ($Na_2C_2O_4$ is dried at 120° C. overnight; 3.35 gm./liter = 0.05 Normal.)

Reagent 44, K (Standard 0.05 Normal Oxalic Acid):

Dissolve 6.31 gm. of $H_2C_2O_4 \cdot 2H_2O$ in distilled water and make up to two liters. Standardize by titrating the oxalic acid, hot (at about boiling point), with 0.05 Normal standard potassium permanganate solution.

Asbestos (Medium Fiber, Powminco, Washed in Acid):

Digest the asbestos in dilute nitric acid (one part of acid to ten parts of distilled water) containing just sufficient potassium permanganate to give a deep purple color. Add more permanganate if the color disappears, and digest for at least 24 hours and until the permanganate color is permanent. Destroy any excess permanganate with oxalic acid, after which the asbestos should be pure white. Wash thoroughly on a Buchner funnel.

Reagent 45, S (Phenolphthalein Indicator):

Dissolve one gm. of phenolphthalein in 100 ml. of alcohol, 95 per cent by volume.

Reagent 46, S (20 Per Cent NaOH Solution):

Dissolve 20 gm. sodium hydroxide, CP pellets in distilled water and make up to 100 ml. with distilled water.

Reagent 47, S (Standardized Copper Sulfate Solution):

Dissolve 139 grams of CP copper sulfate crystals ($CuSO_4 \cdot 5H_2O$) in distilled water and make up to two liters with distilled water.

Standardization: Neutralize 50 ml. of the standard invert sugar solution in a 250-ml. volumetric flask with dilute sodium hydroxide and make up to the mark with distilled water. Pipette five ml. of the alkaline tartrate solution into a 300-ml. Erlenmeyer flask and from an accurate burette measure in exactly five ml. of the copper sulfate solution. Then from a burette run in 24 ml. of the neutralized standard invert sugar solution. Place on an open-top electric hot plate which has been covered by a very thin sheet of asbestos and heat to boiling. Continue the boiling for exactly two minutes and then add five drops of the methylene blue solution. Continue boiling and finish the titration by adding the invert sugar solution from the burette, a few drops at a time, until the blue color just disappears. This titration should require 25.64 ml. of the invert sugar solution. If it takes less than the required amount (25.64 ml.), the copper solution is weak and more of the copper salt must be added to bring it to the required strength. If it takes more than 25.64 ml., the copper solution is too strong and must be diluted to bring it to the proper strength.

Example:

Titration required, 26.40 ml.

Then: $\frac{26.40}{25.64} = 1.0296$ or 29.6 ml. of distilled water per 1,000 ml. of solution must be added to bring the copper solution to the proper strength.

Original quantity of copper solution, 2000 ml.; used 26.4 ml.

Then: $2{,}000 - 26.4 = 1{,}973.6$ ml.

$29.6 \times \frac{1973.6}{1000} = 58.4$ ml. of distilled water to be added to the 1973.6 ml. of copper solution.

Standard Invert Sugar Solution:

Weigh out exactly 9.5 gm. of the best refined sugar obtainable (Con. A), place in a small flask, add five ml. of concentrated HCl and make up to about 100 ml. Allow to stand two or three days if the temperature is over 20° C. (68° F.), or a week if the temperature is below 20° C. Then, without neutralizing, make up to one liter and keep in a well-stoppered bottle. This solution is sufficiently acid to prevent development of microorganisms and will keep for a considerable time. One hundred ml. of this solution contains one gram of invert sugar.

Reagent 48, S (Alkaline Tartrate Solution):

Dissolve 692 gm. of CP potassium sodium tartrate crystals and 200 gm. of CP sodium hydroxide pellets in distilled water. Cool and dilute to two liters.

Reagent 49, S (One Per Cent Methylene Blue Solution):

Dissolve one gm. of a good grade of methylene blue in 100 ml. of distilled water.

Reagent 50, S (6 Normal HCl):

Add one volume of CP HCl to one volume of distilled water.

Reagent 51, P ($Mg(NO_3)_2$ in Alcohol Solution):

Dissolve 1000 gm. of magnesium nitrate in 2500 ml. of 95 per cent alcohol.

Reagent 52, P (2 Normal H_2SO_4):

Take 115 ml. of concentrated 36 Normal sulfuric acid (arsenic and phosphorus-free) and make up to two liters with distilled water.

Reagent 53, P (2,4 Dinitrophenol):

A saturated solution of 2,4 dinitrophenol.

Reagent 54, P (10 Per Cent NaOH):

Dissolve 200 gm. of CP sodium hydroxide pellets in about 1000 ml. of distilled water. Make up to two liters when the solution has cooled.

Ammonium Molybdate Solution (9.6 Normal):

Dissolve 100 gm. of ammonium molybdate in 800 ml. of distilled water heated to 60° C., and filter. Dilute 1100 ml. of arsenic- and phosphorus-free concentrated

H_2SO_4 to 3200 ml. After both solutions have cooled, add the ammonium molybdate solution slowly, with constant shaking, to the sulfuric acid solution. Cool to room temperature and dilute to exactly 4000 ml. This is approximately a 9.6 Normal solution of H_2SO_4 containing 2.5 gm. of ammonium molybdate per 100 ml.

Standard KH_2PO_4 Solution (Five Parts Per Million P):

Dissolve 0.2195 gm. of KH_2PO_4 in distilled water and dilute to one liter. This solution contains 50 parts per million of phosphorus and serves as the base stock solution. Prepare standard phosphate solution by taking 50 ml. of the base stock solution and diluting to 500 ml. with distilled water. This standard solution contains five parts per million of phosphorus.

Experiment Station Checking System

At regular intervals representative portions of analyzed specimens should be forwarded to the Chemistry department, Experiment Station, H.S.P.A., with plantation data. A checking analysis of each specimen will be made at the Experiment Station, the results will be compared with the plantation findings and recommendations forwarded to the plantation based upon the results of the checking study.

Reagents and equipment identical to those used on the plantations are employed in such checking studies. This service is offered gratis as a part of the cooperation tendered by the Experiment Station.

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
MARCH 16, 1944, TO JUNE 15, 1944

Date	Per pound	Per ton	Remarks
March 16, 1944–June 15, 1944	3.74¢	$74.80	Philippines